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Official Secrets Acts.*

C.B. 4182/45

RADAR MANUAL
(Use of Radar)

1945

Admiralty, S.W.1.

17th April, 1945.

R.E. 02889/44.

C.B. 4182/45—Radar Manual—(Use of Radar) having been approved by My Lords Commissioners of the Admiralty is hereby promulgated for information and guidance.

C.B. 4182—Radar Operational Manual March 1942

C.B. 4182A—Addendum to Radar Operational Manual March 1942

C.B. 4182N—Addendum to Radar Operational Manual March 1942

are hereby superseded and are to be destroyed in accordance with Art. 42 of Form U.2.D.

By Command of Their Lordships,

H. V. Markham

To Flag Officers and
Commanding Officers of
H.M. Ships, Vessels and
Shore Establishments
concerned.

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TABLE 1

SOURCES OF INFORMATION ABOUT RADAR

OPERATIONAL USE AND TRAINING

(* Indicates issued only to ships carrying aircraft)

General

C.B. 4182/45	...	...	Radar Manual. (Use of Radar.)
C.B. 3108	...	...	Instructions for the use of radar in merchant vessels.
† C.B. (R) 4180	...	...	Radar operating procedure—General.
B.R.	...	...	Radar exercises.
S.P. 02192 (2)	...	...	Fleet Signal Book.
			Sections 9 and 10—Signals concerning radar generally, including radar and I.F.F. policy signals, state of efficiency signals, and signals for setting and ceasing radar watch, and detailing guardships.
			Article 148A—Radar reports of aircraft (code).
			Article 148B—Code for radar reports of Surface Contacts.
			Article 150—Alarm Signals Table.
			Article 210—Radar Guard duties table.
C.B. 04211	...	...	Fighting experience.

† Note. It is intended to supersede C.B. (R) 4180 and issue revised and amplified information in the following publications:—

- (a) C.B. (R) or B.R.—*Radar Operation—Notes for Operators*. An abridged version of C.B. 4182/45 for radar operators. Will include general descriptions of radar sets and their uses and the technique of operating radar sets and displays, and classifying echoes.
- (b) B.R.—*Operating procedure for Warning Radar*. This will be the counterpart of B.R. 984 (Drill for gunnery radar sets) and will include reporting procedure and also teacher-assisted exercises.
- (c) C.R. (R) or B.R.—*Radar manipulation procedure* issued with the technical handbook of each set, explaining how to manipulate the controls so as to get the best out of the set.
- (d) B.R.—*Radar Training manual*, containing details of courses and syllabuses.

I.F.F. and Radar Beacons

C.B. 04092/44	...	...	Instructions for the use of I.F.F. transponders and radar beacons by Allied forces.
C.B. 04092A/42	...	...	Summary of radar identification (I.F.F., radar beacons, and interrogators).
C.B. 4245	...	...	Instructions for the use of M.A.B. (= Radar beacons in merchant vessels).
S.P. 2560	...	...	Morse groups for use with British Shipborne Racons (= radar beacons).
S.P. 2558 } S.P. 2559 }	...	...	*Location of Racons (= radar beacons)—Atlantic, etc.
C.C.B.P. 01 } C.C.B.P. 02 }	...	...	*Location of Racons (= radar beacons)—Pacific, etc. (issued by U.S. Authorities).

Gunnery

C.B. 3001 (series)	...	...	Progress in naval gunnery.
C.B. (R) 3085	...	...	H.A. Firing Manual.
C.B. (R) 3120 and B.R. 987(4) }	...	...	Gunnery Firing Manual.
C.B. 4112	...	...	Guardbook and Index for pamphlets of the Handbook on the use of radar for gunnery purposes.
C.B. 4112(1)	...	...	Handbook on the use of radar for gunnery purposes—General.

Gunnery—(contd.)

C.B. 4112(2)	...	...	Handbook on the use of radar for gunnery purposes—Continuous prediction unit, Mark I.
C.B. 4112(3)	...	...	Handbook on the use of radar for gunnery purposes—Type 282.
C.B. 4112(4)	...	...	Handbook on the use of radar for gunnery purposes—Type 284.
C.B. 4112(5)	...	...	Handbook on the use of radar for gunnery purposes—Type 285.
C.B. 4112(6)(43)	...	...	Handbook on the use of radar for gunnery purposes—The Auto-barrage unit, Mark I.
C.B. 4112(7)	...	...	Handbook on the use of radar for gunnery purposes—Types 271, 272 and 273.
C.B. 4112(8)	...	...	Handbook on the use of radar for gunnery purposes—Visual/Radar Target Indication.
C.B. 4112(9)	...	...	Handbook on the use of radar for gunnery purposes—Type 274.
C.B. 4112(10)	...	...	Handbook on the use of radar for gunnery purposes—Type 275.
C.B. 4212	...	...	Types 282/4/5M(1) and 282/4/5M(2)—adjustment of frequency to reduce risk of being jammed.
B.R. 984	...	...	Radar operating procedure—Part II—Drill for gunnery radar sets.
B.R.'s (various)	...	...	Drill books for gun mountings and fire control systems.

Fighter Direction

C.B. 04262	...	...	Notes on the direction of fighters by H.M. Ships.
C.B. 4224/44	...	...	Heightfinding by radar.

Torpedo Control

C.B. 4045	...	...	Torpedo Firing Manual.
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Anti-Submarine

C.B. 04050 (series)	...	...	Monthly Anti-submarine report.
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Action Information Organisation

C.B. 04357	...	...	Action Information Organisation.
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Airborne Radar

C.B. 04040	...	...	Naval Air Fighting Instructions.
N.N.	...	...	*Naval Air Tactical Notes.

Shore Radar

C.B. 04271	...	...	Coastal radar stations and Naval plotting organisation.
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Enemy Radar and Radio Counter Measures

C.B. 03067/43	...	...	Enemy radar.
C.B.(R) 4153	...	...	Descriptive pamphlet on radar instructional gramophone records,

Technical

C.B. (R) 3090/44...	...	...	Instructions for installation and fitting of radar equipment and associated communications. <i>Note.</i> Section O contains a list of all current technical handbooks and fitting-out specifications.
R.H. 600 Series	...	...	A.S.E. Technical Bulletin. <i>Note.</i> This publication may also contain notes on current radar operational matters.

TABLE 2
WHAT SET AT A GLANCE.

(For fuller details see Chapter III)

WA=Warning of Aircraft.

WS=Warning of Surface craft.

WC=Warning (Combined Aircraft and Surface).

GS=Gunnery fire control—Surface (i.e. low angle).

GA=Gunnery fire control—Aircraft, high angle (or combined low angle and high angle).

GB=Gunnery fire control—Barrage.

GC=Gunnery fire control—Close Range, High Angle.

TI = Target Indication.

TYPE NUMBER	CLASSIFICATION	REMARKS
242	Interrogator	For use with WS and WC sets.
243	Interrogator	For use with WA sets.
244	Interrogator	For use with U.S. type SL.
245	Interrogator	For Fighter Directing ships.
251M/P	Radar Beacon	—
253	I.F.F. in ships	Mark III system (in force). Type 253P has coding.
255	Radar Beacon	Marker buoy for use only with type 291.
256	Shore radar Beacon	For use only with type 291.
257	Blind Approach Beam System (BABS)	For Aircraft Carriers.
262	GC	Under development to replace type 282.
263	GB	Under development to replace type 283.
267W	WC	For Submarines. Consists of a WS set and WC type 291, which can be used alternatively.
268	WS	For coastal force. Will replace type 291U.
271	WS	For small ships.
272	WS	For small and medium-sized ships.
273	WS	For large and small ships.
274	GS	Successor to type 284.
275	GA	Successor to type 285.
276	WC and TI	To be replaced by type 293.
277	WS	Replacing types 271/2/3. Can measure approximate elevation. See also type 293.
79/279	WA	Long range aircraft warning set for large ships.
281	WA	Long range aircraft warning set for large ships.
282	GC	For pom pom directors, etc.
283	GB	Auto barrage for main or secondary armament.
284	GS	For main armament directors.
285	GA	For H.A. directors. (H.A./L.A. directors in destroyers.)
286	WC	For small ships (obsolete).
288	GC	Type 282, adapted for training ashore.
291	WC	For small ships.
293	WC and TI	For destroyers and above. Where type 277 is not also fitted, type 293 replaces type 271/2/3.
930	GS	Under development as an adjunct to type/s 284/274.
931	GS	Ditto
940	Interrogator	For use with type 980.
941 G-Band	Interrogator	For use with type 281BM.
951	Radar Beacon	Marker beacon for use with 10 centimetre WS and WC sets.
952	Radar Beacon	Marker beacon for use with type 268.
960	WA	Under development to replace type 281B.
970	WS	For small ships, mainly for use in combined operations.
980	WC	Plan display set under development for fighter direction from aircraft carriers.
981	Heightfinder	Under development for use with type 980.
992	WC and TI	Under development to replace type 293.

Suffices :—

B	Adapted for one-mast working.
M, P, Q	1st, 2nd and 3rd major modifications to a type.
R	Accurate ranging panel added.
S	For fixed use on shore.
T	For transportable use on shore.
U	Adapted for fitting in trawlers and coastal force craft.
W	Adapted for fitting in Submarines.
X, Y, Z	1st, 2nd and 3rd experimental models of a new type.

Future allocation of type numbers.

In future, type numbers will be allocated from the following groups :—

900-909	GA sets.
910-919	GB sets.
920-929	GC sets.
930-939	GS sets.
940-949	Interrogators.
950-959	I.F.F. and Radar Beacons
960-969	WA sets.
970-979	WS sets.
980-989	WC and/or accurate Heightfinding sets.
990-000	WC sets.

PRINCIPAL U.S. SETS AND THEIR APPROXIMATE BRITISH EQUIVALENTS

U.S. TYPE	APPROXIMATE BRITISH EQUIVALENT, OR BRIEF DESCRIPTION.
SA	WC 291
SC	WC 291
SF	WS 271
SG	WS 271/3Q
SJ	WS set in Submarines.
SK	WA 79B
SL	WS 271
SM	Fighter Direction and Heightfinding set.
SO	WS 970
SP	Improved SM
SQ	After action WS set.
SU	WS 268.

Modifications are indicated by adding a letter or figure, e.g. SG, SM1A.

Interrogators, I.F.F. and Radar Beacons.

BK	I.F.F. type 253.
BL	Interrogator type 243.
BO	'G' -Band Interrogator type 941.
YJ	Radar Beacon type 251M, but is also for use with ASB in aircraft.

TABLE 3

LIST OF COMMON RADAR TERMS

(The principal terms used for controlling radar are shown in heavy type.)

"A" DISPLAY ...	See "Display."
AIMING ...	Pointing a director or mounting and its associated radar at the present position of a target. "Pointing" includes laying and training. When aiming is carried out by watching a suitable radar display it is called <i>radar aiming</i> .
AMPLIFYING REPORTS ...	All reports of a target subsequent to the first report.
BEAM-SWITCHING...	A method of obtaining accurate bearing and/or elevation of a target by rapid movement of the radar beam, thus producing two echoes. When the echoes are equally matched the bearing is correct.
BEARINGS ...	For warning radar are classified as follows :— 1st Class ... Within 1 degree. 2nd Class ... Within 3 degrees. 3rd Class ... Within 10 degrees. Approximate ... Less accurate than 3rd class.
BLIND FIRE ...	Using radar bearing, range, and if necessary elevation to fire at an unseen target. (It should be noted that blind fire as defined in C.B. 3120 can be carried out without the use of radar, e.g. bombardment; but in this manual the term "Blind Fire" refers only to radar methods.) <i>Radar Bearing Blind Fire</i> —Radar training and ranging, estimated elevation. <i>Full Radar Blind Fire</i> —Radar aiming and ranging.
CALIBRATION ...	There are three forms of radar calibration :— <i>Technical Calibration</i> , e.g. electrical setting up of the trace. <i>Height Calibration</i> , i.e. obtaining the vertical coverage diagram of WA sets, or the correction to be applied to Heightfinding sets. (Chapter II). <i>Gunnery Range Calibration</i> , i.e. obtaining the "radar straddle correction," which is the difference between radar range and hitting true range. (Chapter 12.)
CATHODE RAY TUBE ...	The electrical device normally used to display radar echoes.
CLASSIFICATION ...	Echoes may be classified as large ship, small ship, aircraft, land, etc.
COVERAGE DIAGRAMS ...	(Formerly called "Polar Diagrams") show the areas (horizontal or vertical) within which a target of specified size can be reliably detected at any given instant.
DISPLAY ...	The method of presenting radar echoes to the observer. The most common types are :— "A" Display (formerly called "A' Scan") which shows range (only) of a target when the radar beam is trained on it. Alternatively "A" Display is used with beam-switching to display and match the two echoes. P.P.I. (Plan Position Indicator), which shows simultaneously both range and bearing of targets, and thus gives a complete picture of the surroundings as detected by radar. P.P.I. display requires the aerial to be kept spinning or sweeping. <i>Skiatron</i> : A display involving the optical projection of a form of P.P.I. on to a ground glass screen, to facilitate plotting. Echoes appear as dark paints on a light background, as opposed to P.P.I. where they are normally bright echoes on a dark background. <i>Sector Display</i> which shows on a type of "A" display all echoes within one or more selected small sectors of bearing. <i>Meters</i> are sometimes used to match echoes produced by beam-switching. <i>H.P.I.</i> (Height Position Indicator) which shows elevation, range, and height.
Disregard ...	Is an order to cease reporting a target unless, owing to an important change in its behaviour the operator considers it should be reported again.
Distance ; Range ...	Distance (in sea miles) is used when reporting detections from radar sets whose traces are marked in miles (e.g. WA sets). Range (in yards or hundreds of yards) is used when, reporting detections from radar sets whose traces are marked in yards (e.g. WS, WC and Gunnery Sets).
Echo ...	Is the visible effect of detection of an object, as shown on a radar display.
First Report ...	The initial report of an echo.

Following	...	...	Is the whole process of continuously determining the present position of a target including its bearing, elevation and range. Following therefore includes both aiming and ranging.
GROUND WAVE	...	...	Own ship's radar transmission, breaking through straight to the receiver, makes detection of objects close to the ship difficult or impossible. The part of the trace so obscured is called the "Ground wave."
H.F.P.	...	...	Height Filtering Position. This is the position where all available radar heightfinding information is received, filtered, and passed to where it is required.
H.P.I.	...	...	See "Display."
Holding	...	...	Means concentrating attention on a particular target and passing frequent reports. The order to "hold" means that the sweep or investigation is interrupted until further orders, and all-round warning (and P.P.I. display) is lost.
I.F.F.	...	...	Identification of Friend or Foe. I.F.F. is the term used loosely to describe the Radar Recognition system whereby friendly ships or aircraft can be recognised as such by radar. The system requires an "Interrogator" in own ship and an "I.F.F. Transponder" in the ship or aircraft being detected. Similarly aircraft are fitted with Interrogators (sometimes called "Lucero") to enable them to recognise friendly ships or other aircraft.
Interrogate	...	...	Is an order to train the Interrogator on a target and transmit in order to obtain I.F.F. responses.
Investigate	...	...	Is an order used with warning sets to carry out a special search over a particular sector. The order to "investigate," while in force, means that all-round warning (and P.P.I. display) will be lost. (See also "Searching.")
MAXIMUM RANGE	...	...	The range to which an echo can be held, under normal conditions, after having once been detected. It is unusual, though not impossible, to detect an echo at maximum range.
NOISE	...	...	Sometimes referred to as "Grass" on "A" Display or "Snow" on P.P.I. display, is the background interference in a radar receiver. The height of an echo is usually measured by comparing it to the height of the noise (e.g. "Three times noise").
PAINTING	...	...	As the aerial sweeps round the trace is said to "paint" echoes on a Skiatron, P.P.I. or Sector Display.
P.P.I.	...	...	See "Display."
RACON	...	...	Radar Beacon.
RADAR BEACON	...	...	A type of I.F.F. transponder of which aircraft can obtain the range and bearing for homing purposes. Radar Beacons are also used ashore to assist ships and aircraft.
Ranging	...	...	Means obtaining and transmitting or reporting a continuous series of accurate ranges of a particular target.
R.C.-R.P. RATINGS	...	...	The radar-control and radar-plotting branches of seamen. Radar Control ratings operate gunnery radar sets and the Fire Control Organisation. Radar plotting ratings operate warning radar sets and carry out the associated plotting.
R.D.R.	...	...	Radar Display Room. The compartment of the Action Information Centre where displays from all warning sets, and the H.F.P. are or will be concentrated.
RELIABLE RANGE	...	...	The range at which a given closing target can normally be first detected with a particular radar set, under normal atmospheric and weather conditions. Reliable range is usually less than maximum range.
RESPONSE	...	...	The effect on the trace caused by another ship's or aircraft's I.F.F. transponder or Radar Beacon being triggered.
Resume Sweep	...	...	Carry out the sweep in force immediately prior to the last ordered cessation of sweep.
SATURATION	...	...	Means the maximum height of echo which can be indicated on the cathode ray tube.
SCANNING	...	...	The technical process whereby some radar sets automatically search in azimuth or in elevation, or in both simultaneously.
SEARCHING	...	...	Is an order used with gunnery radar sets to carry out a special search over a particular sector or near a particular bearing or angle of sight. It is the counterpart of the term "Investigating" used with warning sets. Searching may be carried out in azimuth or in elevation, or in both simultaneously; and can be done manually or automatically (by "scanning").

Single-Few-Group	...	...	When reporting detections of aircraft, the following rough categories are used :—
		(a) Single	... One aircraft.
		(b) Few	... Two to six aircraft in a body.
		(c) Group	... More than six aircraft in a body.
			Alternatively the approximate number may be reported (e.g. "Ten plus").
SKIATRON	...	...	See "Display."
SPINNING :	...	...	Rapid automatic and continuous sweeping of a radar aerial.
SPLASH SPOTTING	...	...	The technique of observing fall of shot by radar.
STROBE	...	...	An electrical range marker operated in conjunction with a range transmission system. It usually takes the form of a bright spot which can be moved along the trace. The strobe can also be used for pointing out a particular echo to a remote position.
Sweeping	...	...	Continuous movement in azimuth of a radar aerial, layed horizontally or at a fixed elevation at the most efficient speed in order to maintain an all-round look-out (or look-out in a special sector if ordered).
Target	...	...	The term used generally to refer to an echo which is receiving particular attention, e.g. which is being watched, held, or ranged on.
T.I.R.	...	...	Target Indication Room. The compartment or part of a compartment of the Action Information Centre which contains the display from the Target Indicating radar set, and the Target Indicating Unit.
T.I.U.	...	...	Target Indicating Unit. An instrument for transmitting bearings and ranges of one or more targets from the Target Indicating radar set to outlying fire control positions.
TRACE	...	...	The line of light traced out on the face of the Cathode ray tube, thus displaying the ground wave, echoes, I.F.F. responses, and "noise."
Tracking	...	...	Means plotting successive bearings and distances of a target and thus deducing its course and speed.
Watching	...	...	Using "A" Display, "Watching" means paying particular attention to one or more echoes and reporting them in detail on each occasion of sweeping past. With P.P.I. display the target is reported about once a minute, or as ordered. The order to "Watch" does not alter the type or rate of sweep previously ordered.
WAVE CLUTTER	...	...	Interference on the trace caused by detection of waves or swell which, together with the ground wave, may make detection of targets close to the ship difficult or impossible.

PART I.

GENERAL DESCRIPTION OF RADAR. ITS CAPABILITIES AND LIMITATIONS. TYPES OF RADAR, AND RADAR EQUIPMENTS.

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Admiralty, S.W.1.

17th April, 1945.

R.E. 02889/44.

C.B. 4182/45—Radar Manual—(Use of Radar) having been approved by My Lords Commissioners of the Admiralty is hereby promulgated for information and guidance.

C.B. 4182—Radar Operational Manual March 1942

C.B. 4182A—Addendum to Radar Operational Manual March 1942

C.B. 4182N—Addendum to Radar Operational Manual March 1942

are hereby superseded and are to be destroyed in accordance with Art. 42 of Form U.2.D.

By Command of Their Lordships,

H. V. Markham

To Flag Officers and
Commanding Officers of
H.M. Ships, Vessels and
Shore Establishments
concerned.

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TABLE 1

SOURCES OF INFORMATION ABOUT RADAR

OPERATIONAL USE AND TRAINING

(* Indicates issued only to ships carrying aircraft)

General

C.B. 4182/45	...	...	Radar Manual. (Use of Radar.)
C.B. 3108	...	...	Instructions for the use of radar in merchant vessels.
† C.B. (R) 4180	...	...	Radar operating procedure—General.
B.R.	...	...	Radar exercises.
S.P. 02192 (2)	...	...	Fleet Signal Book.
			Sections 9 and 10—Signals concerning radar generally, including radar and I.F.F. policy signals, state of efficiency signals, and signals for setting and ceasing radar watch, and detailing guardships.
			Article 148A—Radar reports of aircraft (code).
			Article 148B—Code for radar reports of Surface Contacts.
			Article 150—Alarm Signals Table.
			Article 210—Radar Guard duties table.
C.B. 04211	...	...	Fighting experience.

† Note. It is intended to supersede C.B. (R) 4180 and issue revised and amplified information in the following publications:—

- (a) C.B. (R) or B.R.—*Radar Operation—Notes for Operators*. An abridged version of C.B. 4182/45 for radar operators. Will include general descriptions of radar sets and their uses and the technique of operating radar sets and displays, and classifying echoes.
- (b) B.R.—*Operating procedure for Warning Radar*. This will be the counterpart of B.R. 984 (Drill for gunnery radar sets) and will include reporting procedure and also teacher-assisted exercises.
- (c) C.R. (R) or B.R.—*Radar manipulation procedure* issued with the technical handbook of each set, explaining how to manipulate the controls so as to get the best out of the set.
- (d) B.R.—*Radar Training manual*, containing details of courses and syllabuses.

I.F.F. and Radar Beacons

C.B. 04092/44	...	...	Instructions for the use of I.F.F. transponders and radar beacons by Allied forces.
C.B. 04092A/42	...	...	Summary of radar identification (I.F.F., radar beacons, and interrogators).
C.B. 4245	...	...	Instructions for the use of M.A.B. (= Radar beacons in merchant vessels).
S.P. 2560	...	...	Morse groups for use with British Shipborne Racons (= radar beacons).
S.P. 2558 } S.P. 2559 }	...	...	*Location of Racons (= radar beacons)—Atlantic, etc.
C.C.B.P. 01 } C.C.B.P. 02 }	...	...	*Location of Racons (= radar beacons)—Pacific, etc. (issued by U.S. Authorities).

Gunnery

C.B. 3001 (series)	...	...	Progress in naval gunnery.
C.B. (R) 3085	...	...	H.A. Firing Manual.
C.B. (R) 3120 and B.R. 987(4) }	...	...	Gunnery Firing Manual.
C.B. 4112	...	...	Guardbook and Index for pamphlets of the Handbook on the use of radar for gunnery purposes.
C.B. 4112(1)	...	...	Handbook on the use of radar for gunnery purposes—General.

Gunnery—(contd.)

C.B. 4112(2)	...	...	Handbook on the use of radar for gunnery purposes—Continuous prediction unit, Mark I.
C.B. 4112(3)	...	...	Handbook on the use of radar for gunnery purposes—Type 282.
C.B. 4112(4)	...	...	Handbook on the use of radar for gunnery purposes—Type 284.
C.B. 4112(5)	...	...	Handbook on the use of radar for gunnery purposes—Type 285.
C.B. 4112(6)(43)	...	...	Handbook on the use of radar for gunnery purposes—The Auto-barrage unit, Mark I.
C.B. 4112(7)	...	...	Handbook on the use of radar for gunnery purposes—Types 271, 272 and 273.
C.B. 4112(8)	...	...	Handbook on the use of radar for gunnery purposes—Visual/Radar Target Indication.
C.B. 4112(9)	...	...	Handbook on the use of radar for gunnery purposes—Type 274.
C.B. 4112(10)	...	...	Handbook on the use of radar for gunnery purposes—Type 275.
C.B. 4212	...	...	Types 282/4/5M(1) and 282/4/5M(2)—adjustment of frequency to reduce risk of being jammed.
B.R. 984	...	...	Radar operating procedure—Part II—Drill for gunnery radar sets.
B.R.'s (various)	...	...	Drill books for gun mountings and fire control systems.

Fighter Direction

C.B. 04262	...	...	Notes on the direction of fighters by H.M. Ships.
C.B. 4224/44	...	...	Heightfinding by radar.

Torpedo Control

C.B. 4045	...	...	Torpedo Firing Manual.
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Anti-Submarine

C.B. 04050 (series)	...	...	Monthly Anti-submarine report.
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Action Information Organisation

C.B. 04357	...	...	Action Information Organisation.
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Airborne Radar

C.B. 04040	...	...	Naval Air Fighting Instructions.
N.N.	...	...	*Naval Air Tactical Notes.

Shore Radar

C.B. 04271	...	...	Coastal radar stations and Naval plotting organisation.
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Enemy Radar and Radio Counter Measures

C.B. 03067/43	...	...	Enemy radar.
C.B.(R) 4153	...	...	Descriptive pamphlet on radar instructional gramophone records,

Technical

C.B. (R) 3090/44...	...	...	Instructions for installation and fitting of radar equipment and associated communications. <i>Note.</i> Section O contains a list of all current technical handbooks and fitting-out specifications.
R.H. 600 Series	...	...	A.S.E. Technical Bulletin. <i>Note.</i> This publication may also contain notes on current radar operational matters.

TABLE 2
WHAT SET AT A GLANCE.

(For fuller details see Chapter III)

WA=Warning of Aircraft.

WS=Warning of Surface craft.

WC=Warning (Combined Aircraft and Surface).

GS=Gunnery fire control—Surface (i.e. low angle).

GA=Gunnery fire control—Aircraft, high angle (or combined low angle and high angle).

GB=Gunnery fire control—Barrage.

GC=Gunnery fire control—Close Range, High Angle.

TI = Target Indication.

TYPE NUMBER	CLASSIFICATION	REMARKS
242	Interrogator	For use with WS and WC sets.
243	Interrogator	For use with WA sets.
244	Interrogator	For use with U.S. type SL.
245	Interrogator	For Fighter Directing ships.
251M/P	Radar Beacon	—
253	I.F.F. in ships	Mark III system (in force). Type 253P has coding.
255	Radar Beacon	Marker buoy for use only with type 291.
256	Shore radar Beacon	For use only with type 291.
257	Blind Approach Beam System (BABS)	For Aircraft Carriers.
262	GC	Under development to replace type 282.
263	GB	Under development to replace type 283.
267W	WC	For Submarines. Consists of a WS set and WC type 291, which can be used alternatively.
268	WS	For coastal force. Will replace type 291U.
271	WS	For small ships.
272	WS	For small and medium-sized ships.
273	WS	For large and small ships.
274	GS	Successor to type 284.
275	GA	Successor to type 285.
276	WC and TI	To be replaced by type 293.
277	WS	Replacing types 271/2/3. Can measure approximate elevation. See also type 293.
79/279	WA	Long range aircraft warning set for large ships.
281	WA	Long range aircraft warning set for large ships.
282	GC	For pom pom directors, etc.
283	GB	Auto barrage for main or secondary armament.
284	GS	For main armament directors.
285	GA	For H.A. directors. (H.A./L.A. directors in destroyers.)
286	WC	For small ships (obsolete).
288	GC	Type 282, adapted for training ashore.
291	WC	For small ships.
293	WC and TI	For destroyers and above. Where type 277 is not also fitted, type 293 replaces type 271/2/3.
930	GS	Under development as an adjunct to type/s 284/274.
931	GS	Ditto
940	Interrogator	For use with type 980.
941 G-Band	Interrogator	For use with type 281BM.
951	Radar Beacon	Marker beacon for use with 10 centimetre WS and WC sets.
952	Radar Beacon	Marker beacon for use with type 268.
960	WA	Under development to replace type 281B.
970	WS	For small ships, mainly for use in combined operations.
980	WC	Plan display set under development for fighter direction from aircraft carriers.
981	Heightfinder	Under development for use with type 980.
992	WC and TI	Under development to replace type 293.

Suffices :—

B	Adapted for one-mast working.
M, P, Q	1st, 2nd and 3rd major modifications to a type.
R	Accurate ranging panel added.
S	For fixed use on shore.
T	For transportable use on shore.
U	Adapted for fitting in trawlers and coastal force craft.
W	Adapted for fitting in Submarines.
X, Y, Z	1st, 2nd and 3rd experimental models of a new type.

Future allocation of type numbers.

In future, type numbers will be allocated from the following groups :—

900-909	GA sets.
910-919	GB sets.
920-929	GC sets.
930-939	GS sets.
940-949	Interrogators.
950-959	I.F.F. and Radar Beacons
960-969	WA sets.
970-979	WS sets.
980-989	WC and/or accurate Heightfinding sets.
990-000	WC sets.

PRINCIPAL U.S. SETS AND THEIR APPROXIMATE BRITISH EQUIVALENTS

U.S. TYPE	APPROXIMATE BRITISH EQUIVALENT, OR BRIEF DESCRIPTION.
SA	WC 291
SC	WC 291
SF	WS 271
SG	WS 271/3Q
SJ	WS set in Submarines.
SK	WA 79B
SL	WS 271
SM	Fighter Direction and Heightfinding set.
SO	WS 970
SP	Improved SM
SQ	After action WS set.
SU	WS 268.

Modifications are indicated by adding a letter or figure, e.g. SG, SM1A.

Interrogators, I.F.F. and Radar Beacons.

BK	I.F.F. type 253.
BL	Interrogator type 243.
BO	'G'-Band Interrogator type 941.
YJ	Radar Beacon type 251M, but is also for use with ASB in aircraft.

TABLE 3

LIST OF COMMON RADAR TERMS

(The principal terms used for controlling radar are shown in heavy type.)

"A" DISPLAY ...	See "Display."
AIMING ...	Pointing a director or mounting and its associated radar at the present position of a target. "Pointing" includes laying and training. When aiming is carried out by watching a suitable radar display it is called <i>radar aiming</i> .
AMPLIFYING REPORTS ...	All reports of a target subsequent to the first report.
BEAM-SWITCHING...	A method of obtaining accurate bearing and/or elevation of a target by rapid movement of the radar beam, thus producing two echoes. When the echoes are equally matched the bearing is correct.
BEARINGS ...	For warning radar are classified as follows :— 1st Class ... Within 1 degree. 2nd Class ... Within 3 degrees. 3rd Class ... Within 10 degrees. Approximate ... Less accurate than 3rd class.
BLIND FIRE ...	Using radar bearing, range, and if necessary elevation to fire at an unseen target. (It should be noted that blind fire as defined in C.B. 3120 can be carried out without the use of radar, e.g. bombardment; but in this manual the term "Blind Fire" refers only to radar methods.) <i>Radar Bearing Blind Fire</i> —Radar training and ranging, estimated elevation. <i>Full Radar Blind Fire</i> —Radar aiming and ranging.
CALIBRATION ...	There are three forms of radar calibration :— <i>Technical Calibration</i> , e.g. electrical setting up of the trace. <i>Height Calibration</i> , i.e. obtaining the vertical coverage diagram of WA sets, or the correction to be applied to Heightfinding sets. (Chapter II). <i>Gunnery Range Calibration</i> , i.e. obtaining the "radar straddle correction," which is the difference between radar range and hitting true range. (Chapter 12.)
CATHODE RAY TUBE ...	The electrical device normally used to display radar echoes.
CLASSIFICATION ...	Echoes may be classified as large ship, small ship, aircraft, land, etc.
COVERAGE DIAGRAMS ...	(Formerly called "Polar Diagrams") show the areas (horizontal or vertical) within which a target of specified size can be reliably detected at any given instant.
DISPLAY ...	The method of presenting radar echoes to the observer. The most common types are :— "A" Display (formerly called "A' Scan") which shows range (only) of a target when the radar beam is trained on it. Alternatively "A" Display is used with beam-switching to display and match the two echoes. P.P.I. (Plan Position Indicator), which shows simultaneously both range and bearing of targets, and thus gives a complete picture of the surroundings as detected by radar. P.P.I. display requires the aerial to be kept spinning or sweeping. <i>Skiatron</i> : A display involving the optical projection of a form of P.P.I. on to a ground glass screen, to facilitate plotting. Echoes appear as dark paints on a light background, as opposed to P.P.I. where they are normally bright echoes on a dark background. <i>Sector Display</i> which shows on a type of "A" display all echoes within one or more selected small sectors of bearing. <i>Meters</i> are sometimes used to match echoes produced by beam-switching. <i>H.P.I.</i> (Height Position Indicator) which shows elevation, range, and height.
Disregard ...	Is an order to cease reporting a target unless, owing to an important change in its behaviour the operator considers it should be reported again.
Distance ; Range ...	Distance (in sea miles) is used when reporting detections from radar sets whose traces are marked in miles (e.g. WA sets). Range (in yards or hundreds of yards) is used when, reporting detections from radar sets whose traces are marked in yards (e.g. WS, WC and Gunnery Sets).
Echo ...	Is the visible effect of detection of an object, as shown on a radar display.
First Report ...	The initial report of an echo.

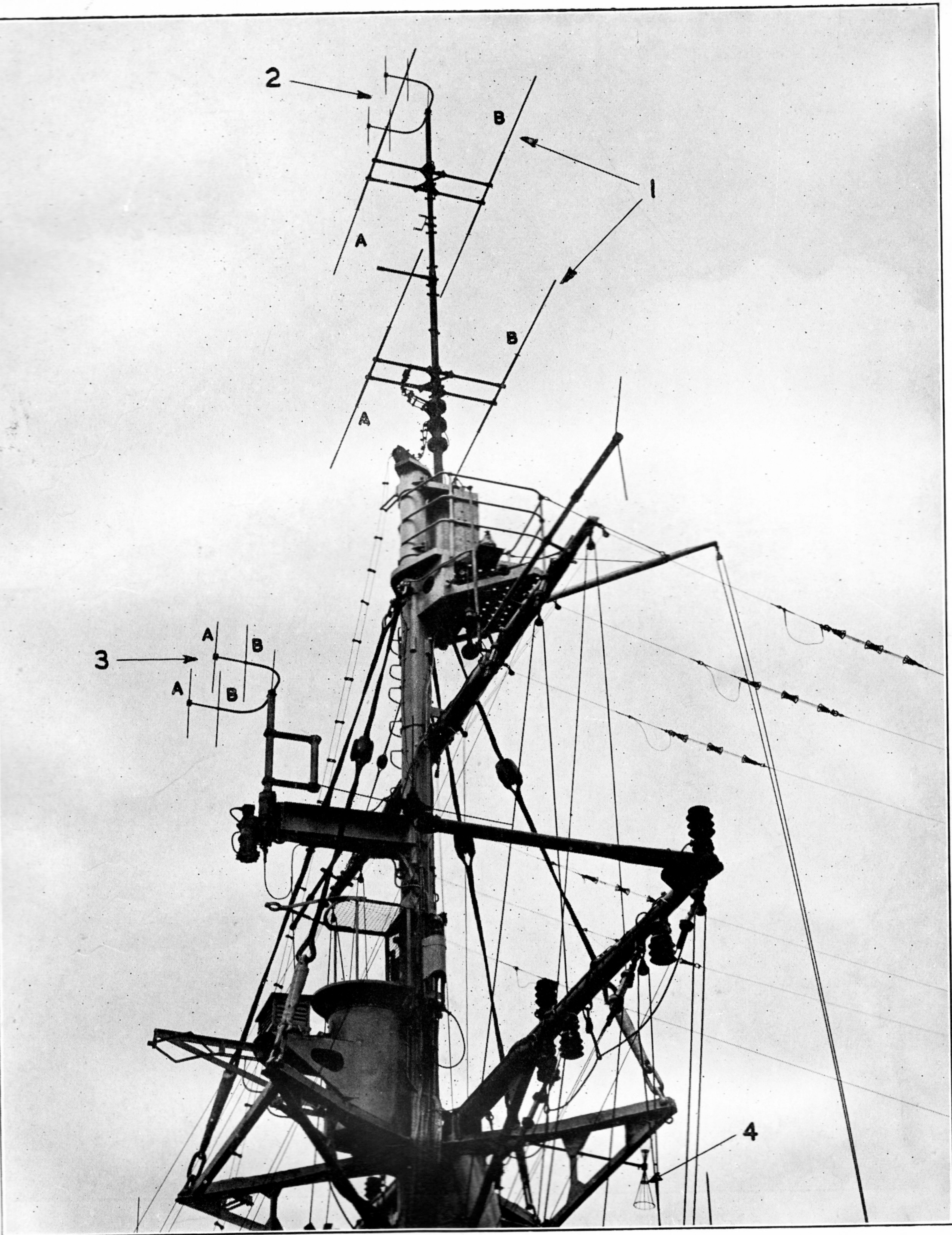
Following	...	...	Is the whole process of continuously determining the present position of a target including its bearing, elevation and range. Following therefore includes both aiming and ranging.
GROUND WAVE	...	...	Own ship's radar transmission, breaking through straight to the receiver, makes detection of objects close to the ship difficult or impossible. The part of the trace so obscured is called the "Ground wave."
H.F.P.	...	...	Height Filtering Position. This is the position where all available radar heightfinding information is received, filtered, and passed to where it is required.
H.P.I.	...	...	See "Display."
Holding	...	...	Means concentrating attention on a particular target and passing frequent reports. The order to "hold" means that the sweep or investigation is interrupted until further orders, and all-round warning (and P.P.I. display) is lost.
I.F.F.	...	...	Identification of Friend or Foe. I.F.F. is the term used loosely to describe the Radar Recognition system whereby friendly ships or aircraft can be recognised as such by radar. The system requires an "Interrogator" in own ship and an "I.F.F. Transponder" in the ship or aircraft being detected. Similarly aircraft are fitted with Interrogators (sometimes called "Lucero") to enable them to recognise friendly ships or other aircraft.
Interrogate	...	...	Is an order to train the Interrogator on a target and transmit in order to obtain I.F.F. responses.
Investigate	...	...	Is an order used with warning sets to carry out a special search over a particular sector. The order to "investigate," while in force, means that all-round warning (and P.P.I. display) will be lost. (See also "Searching.")
MAXIMUM RANGE	...	...	The range to which an echo can be held, under normal conditions, after having once been detected. It is unusual, though not impossible, to detect an echo at maximum range.
NOISE	...	...	Sometimes referred to as "Grass" on "A" Display or "Snow" on P.P.I. display, is the background interference in a radar receiver. The height of an echo is usually measured by comparing it to the height of the noise (e.g. "Three times noise").
PAINTING	...	...	As the aerial sweeps round the trace is said to "paint" echoes on a Skiatron, P.P.I. or Sector Display.
P.P.I.	...	...	See "Display."
RACON	...	...	Radar Beacon.
RADAR BEACON	...	...	A type of I.F.F. transponder of which aircraft can obtain the range and bearing for homing purposes. Radar Beacons are also used ashore to assist ships and aircraft.
Ranging	...	...	Means obtaining and transmitting or reporting a continuous series of accurate ranges of a particular target.
R.C.-R.P. RATINGS	...	...	The radar-control and radar-plotting branches of seamen. Radar Control ratings operate gunnery radar sets and the Fire Control Organisation. Radar plotting ratings operate warning radar sets and carry out the associated plotting.
R.D.R.	...	...	Radar Display Room. The compartment of the Action Information Centre where displays from all warning sets, and the H.F.P. are or will be concentrated.
RELIABLE RANGE	...	...	The range at which a given closing target can normally be first detected with a particular radar set, under normal atmospheric and weather conditions. Reliable range is usually less than maximum range.
RESPONSE	...	...	The effect on the trace caused by another ship's or aircraft's I.F.F. transponder or Radar Beacon being triggered.
Resume Sweep	...	...	Carry out the sweep in force immediately prior to the last ordered cessation of sweep.
SATURATION	...	...	Means the maximum height of echo which can be indicated on the cathode ray tube.
SCANNING	...	...	The technical process whereby some radar sets automatically search in azimuth or in elevation, or in both simultaneously.
SEARCHING	...	...	Is an order used with gunnery radar sets to carry out a special search over a particular sector or near a particular bearing or angle of sight. It is the counterpart of the term "Investigating" used with warning sets. Searching may be carried out in azimuth or in elevation, or in both simultaneously; and can be done manually or automatically (by "scanning").

Single-Few-Group	...	...	When reporting detections of aircraft, the following rough categories are used :—
		(a) Single	... One aircraft.
		(b) Few	... Two to six aircraft in a body.
		(c) Group	... More than six aircraft in a body.
			Alternatively the approximate number may be reported (<i>e.g.</i> "Ten plus").
SKIATRON	...	...	See "Display."
SPINNING :	...	...	Rapid automatic and continuous sweeping of a radar aerial.
SPLASH SPOTTING	...	...	The technique of observing fall of shot by radar.
STROBE	...	...	An electrical range marker operated in conjunction with a range transmission system. It usually takes the form of a bright spot which can be moved along the trace. The strobe can also be used for pointing out a particular echo to a remote position.
Sweeping	...	...	Continuous movement in azimuth of a radar aerial, layed horizontally or at a fixed elevation at the most efficient speed in order to maintain an all-round look-out (or look-out in a special sector if ordered).
Target	...	...	The term used generally to refer to an echo which is receiving particular attention, <i>e.g.</i> which is being watched, held, or ranged on.
T.I.R.	...	...	Target Indication Room. The compartment or part of a compartment of the Action Information Centre which contains the display from the Target Indicating radar set, and the Target Indicating Unit.
T.I.U.	...	...	Target Indicating Unit. An instrument for transmitting bearings and ranges of one or more targets from the Target Indicating radar set to outlying fire control positions.
TRACE	...	...	The line of light traced out on the face of the Cathode ray tube, thus displaying the ground wave, echoes, I.F.F. responses, and "noise."
Tracking	...	...	Means plotting successive bearings and distances of a target and thus deducing its course and speed.
Watching	...	...	Using "A" Display, "Watching" means paying particular attention to one or more echoes and reporting them in detail on each occasion of sweeping past. With P.P.I. display the target is reported about once a minute, or as ordered. The order to "Watch" does not alter the type or rate of sweep previously ordered.
WAVE CLUTTER	...	...	Interference on the trace caused by detection of waves or swell which, together with the ground wave, may make detection of targets close to the ship difficult or impossible.

PART I.

GENERAL DESCRIPTION OF RADAR. ITS CAPABILITIES AND LIMITATIONS. TYPES OF RADAR, AND RADAR EQUIPMENTS.

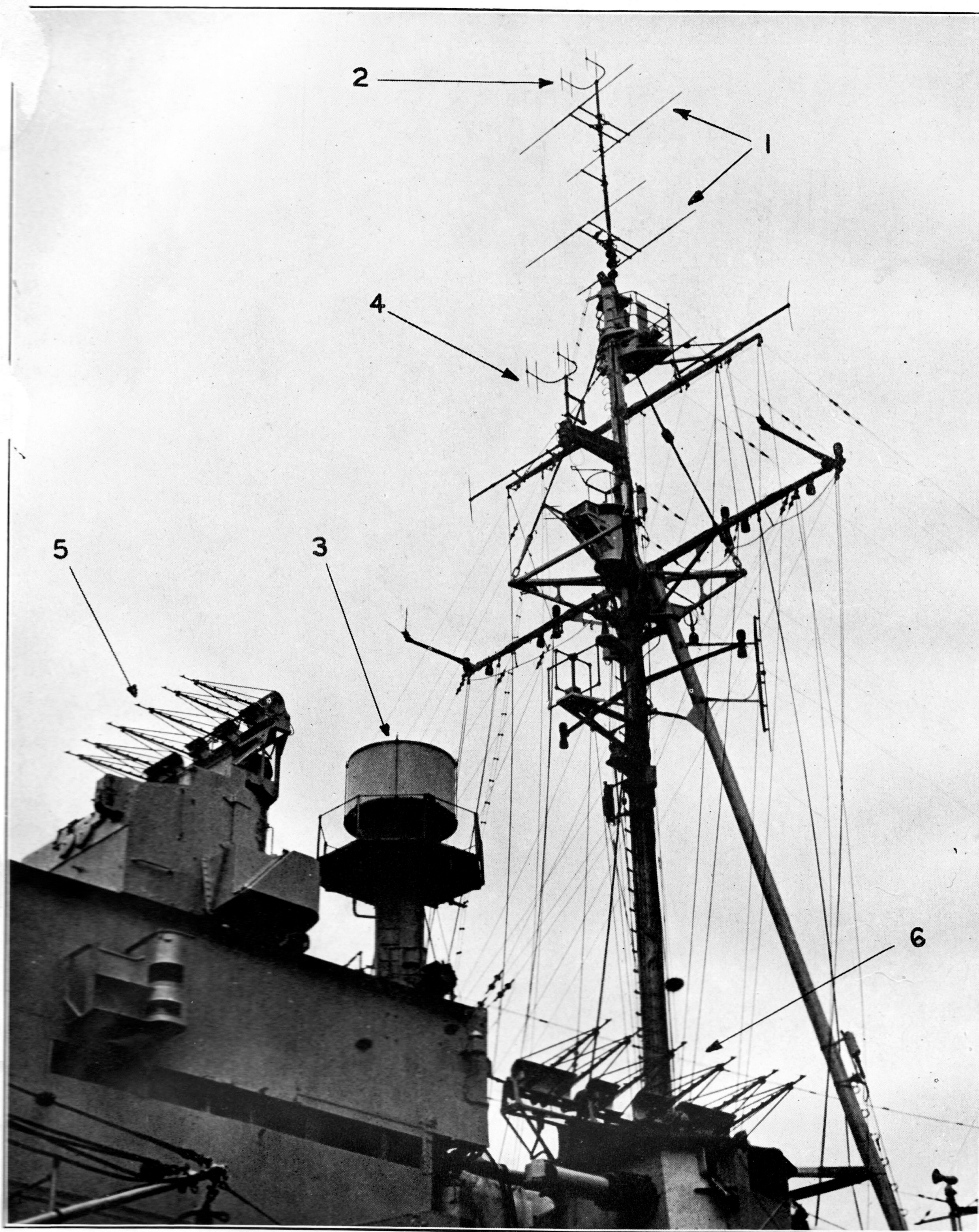
	Page
CHAPTER I. Introduction and Summary	17
" II. How Radar Works	20
" III. Types of Radar and their capabilities	35
" IV. Typical Radar Equipments of Ships	48
" V. Limitations	49



PHOTOGRAPH 1—General view of Cruiser's mast showing following aerials :—

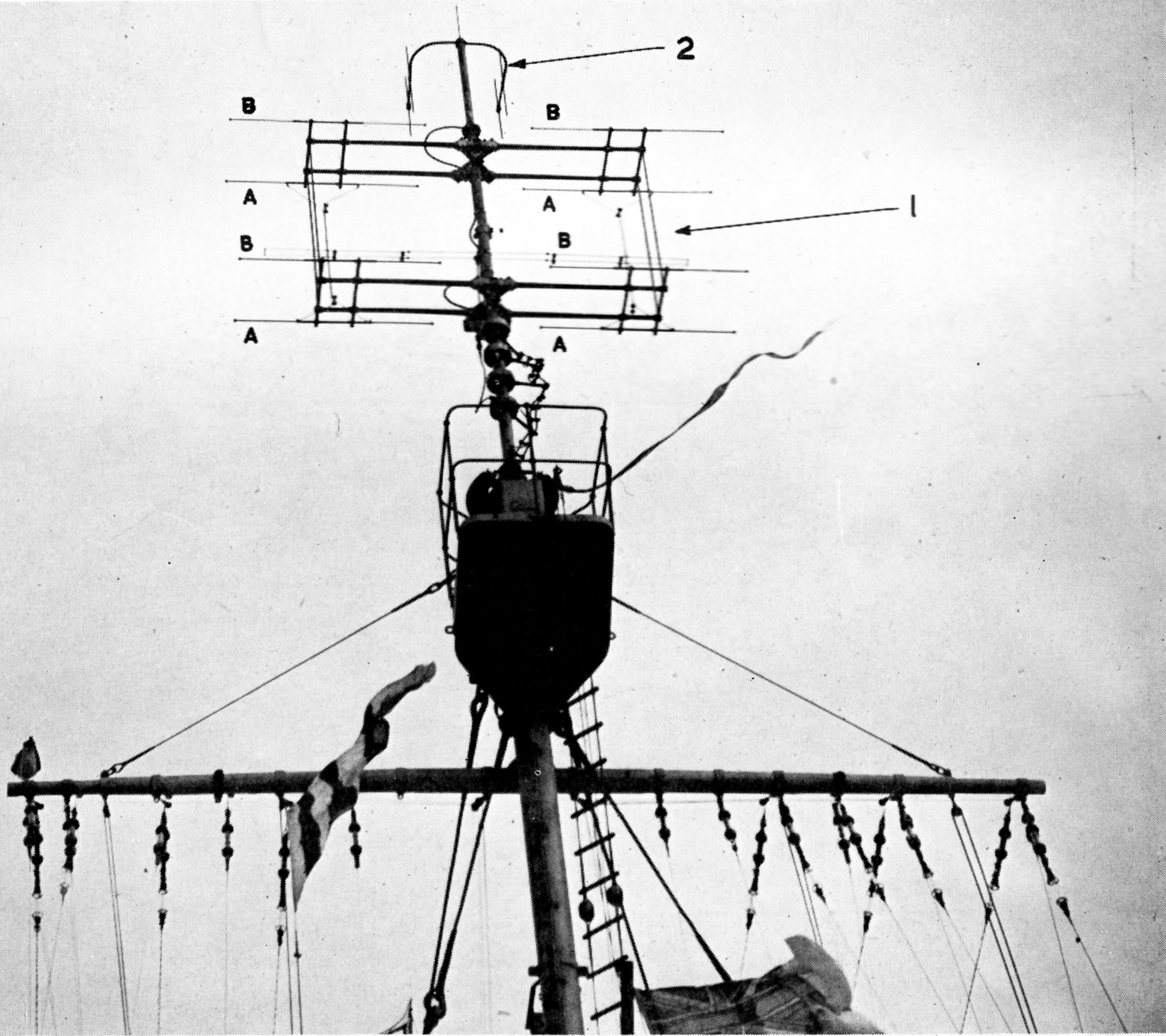
- 1.—WA type 279.
- 2.—Directional Interrogator type 243 (for use with WA type 279).
- 3.—Directional Interrogator type 242 (for use with WS set, not shown).
- 4.—Conical aerial used with I.F.F. type 253. Similar aerials are used with all-round Interrogators, type 91, and certain search receivers.

Note.—In photographs of Group I " A " indicates the aerials (or waveguide mouths) and " B " the reflectors.



PHOTOGRAPH 2—General view of Cruiser's mast and Superstructure showing following radar aerials :—

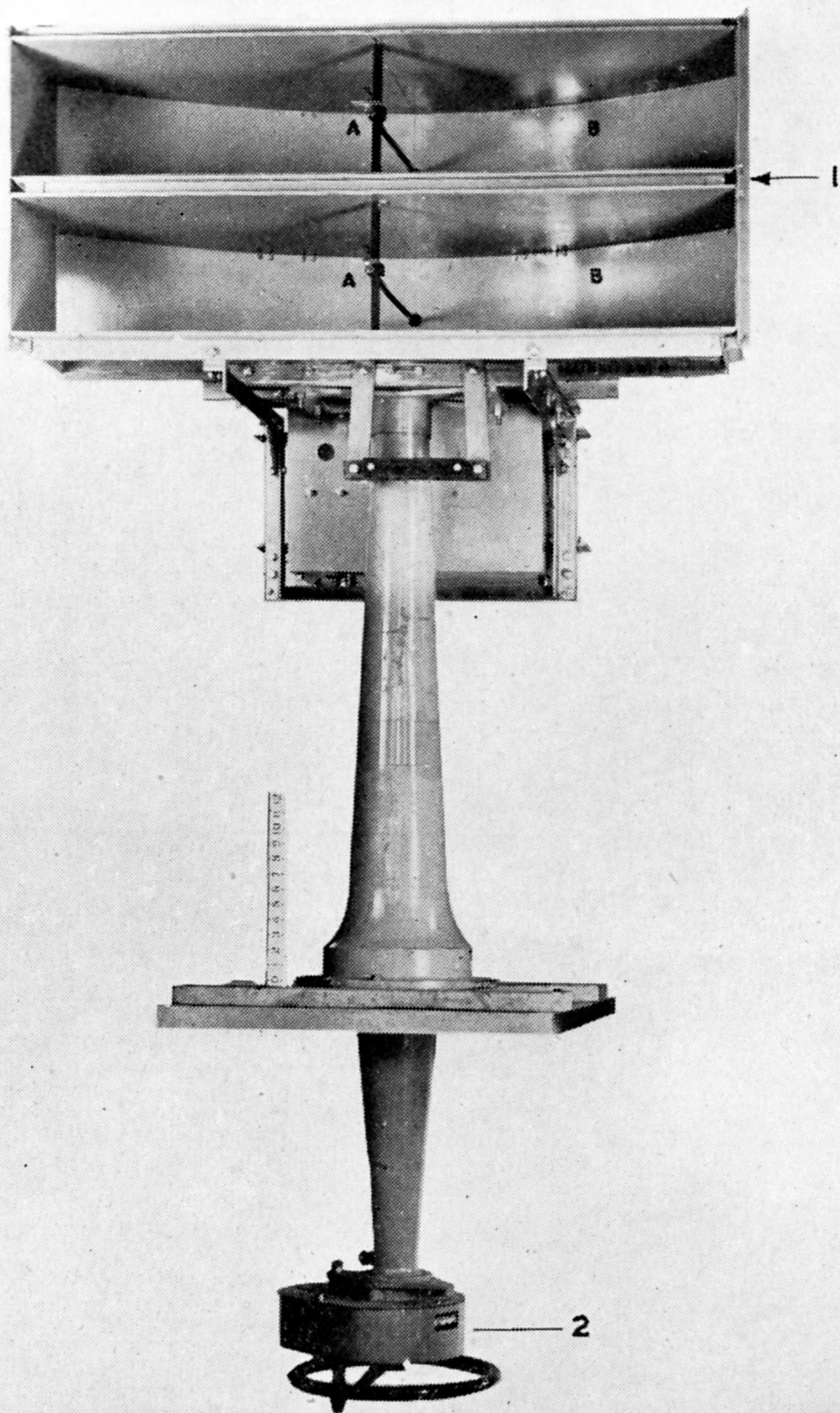
- 1.—WA type 279.
- 2.—Interrogator type 243 (for use with WA set).
- 3.—WS type 271P (aerial enclosed in perspex lantern).
- 4.—Interrogator type 242 (for use with WS set).
- 5.—GS type 284 (with fishbone type aerial ASG) on L.A. Director.
- 6.—GA type 285 on H.A. Director.



PHOTOGRAPH 3—showing :—

1.—*WA type 281B* aerial.

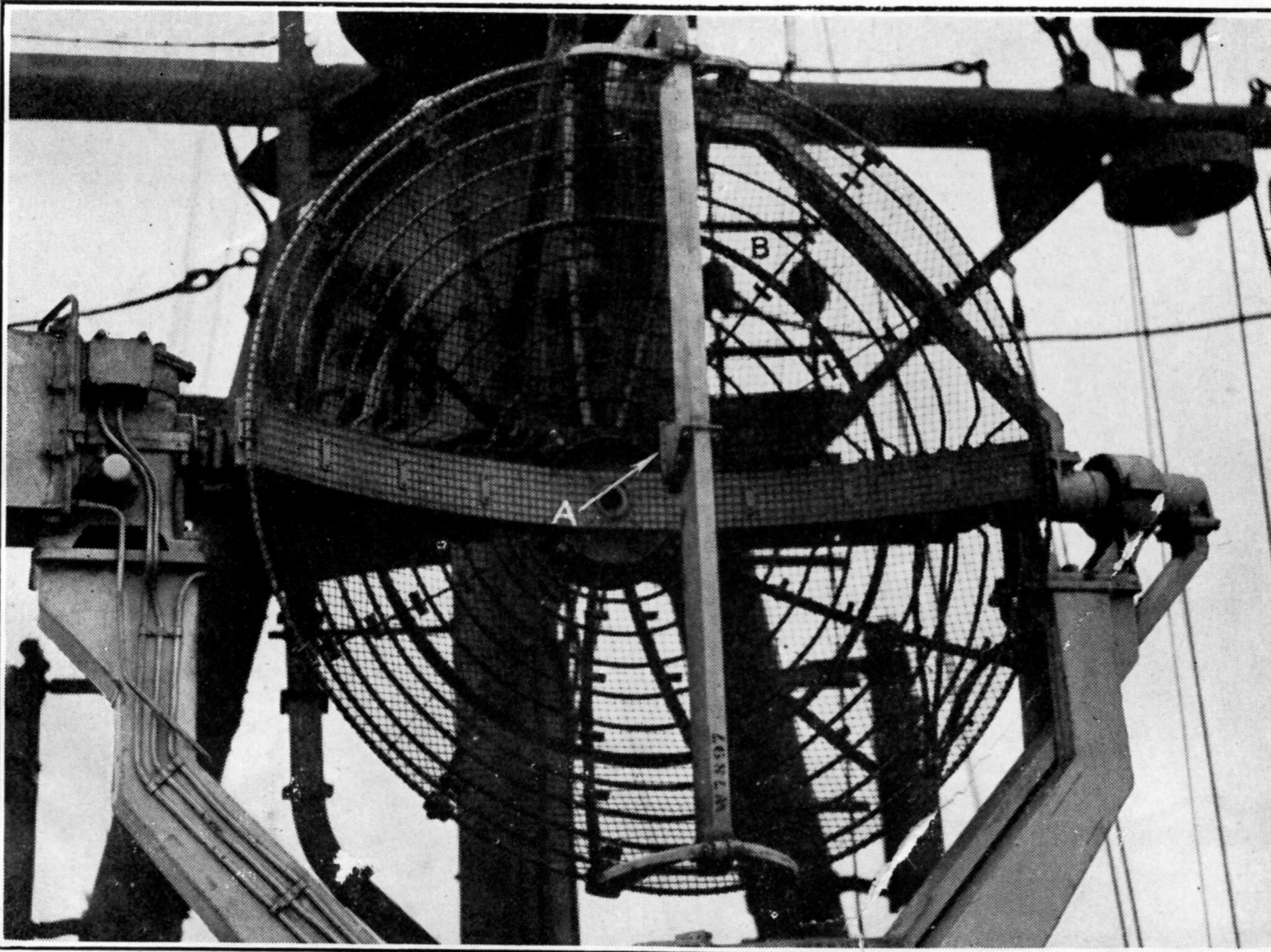
2.—Directional Interrogator type 243.



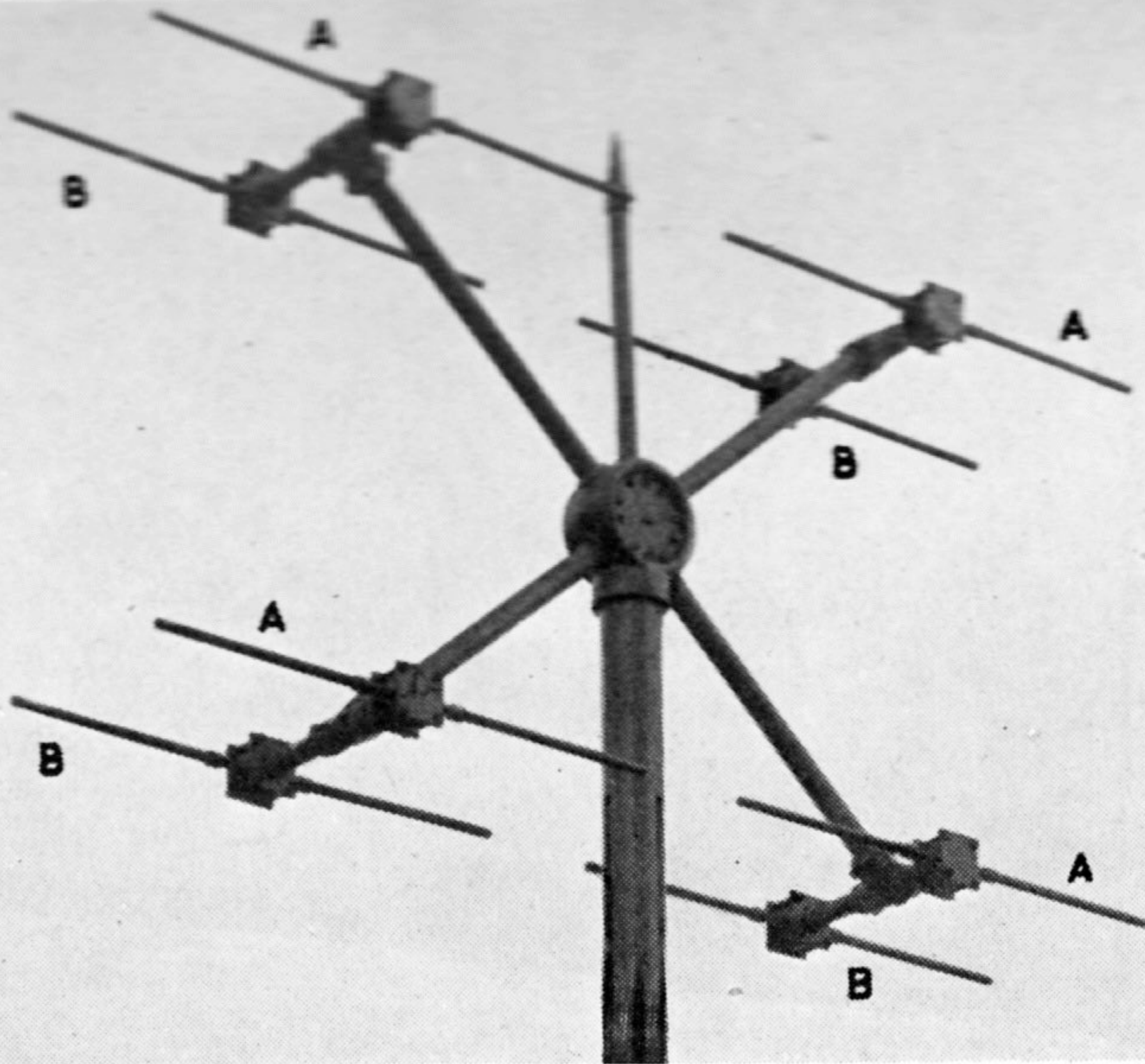
PHOTOGRAPH 4—*WS type 271* aerial exposed to view by removal of perspex lantern.

1.—“ Cheese ” type parabolic reflectors for transmitting and receiving aerals.

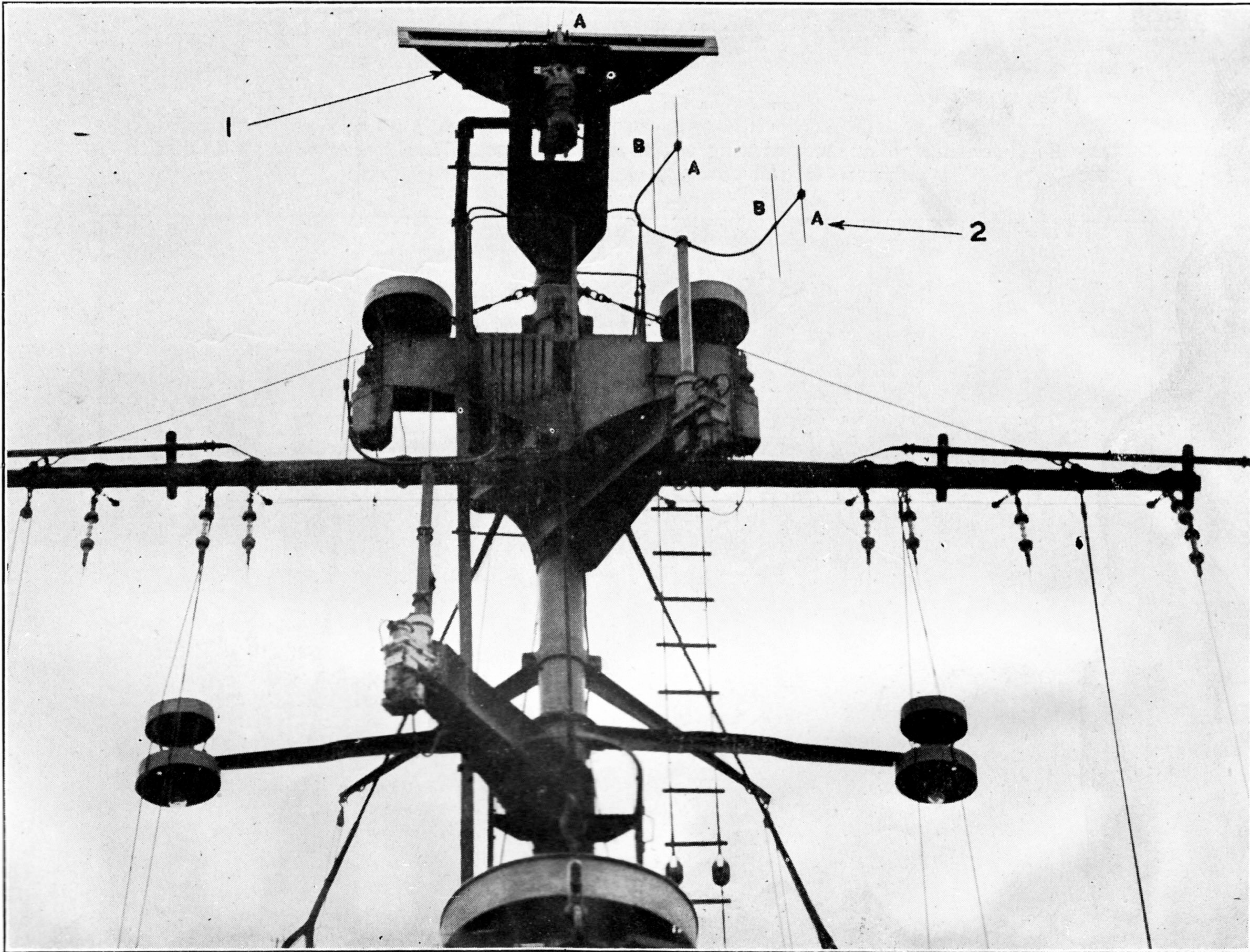
2.—Aerial training handwheel (in radar office).



PHOTOGRAPH 5—View of *WS type 277* aerial system, showing waveguide mouth (A) and mesh-type full parabolic reflector (B).

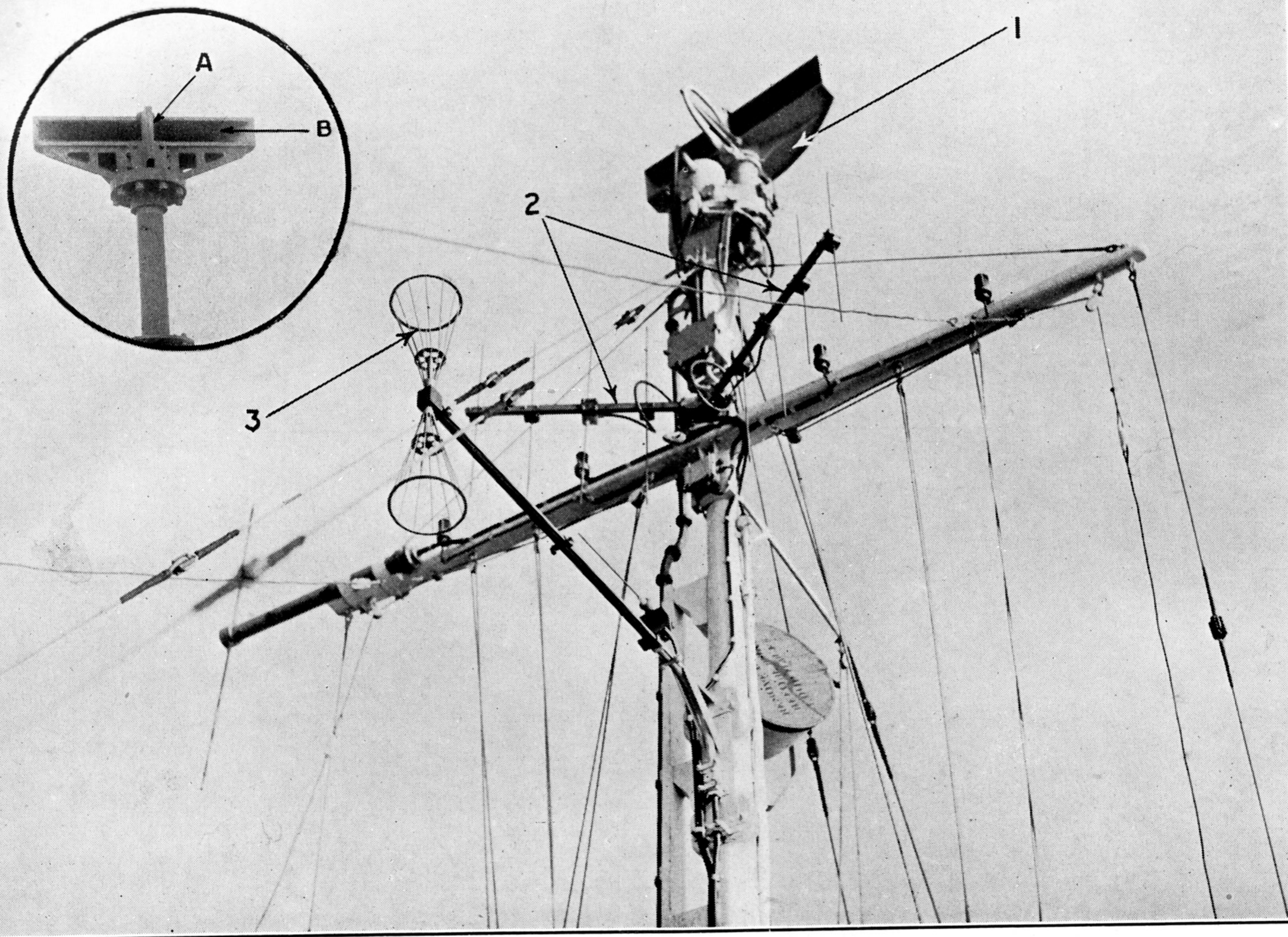


PHOTOGRAPH 6—*WC type 291* aerial.



PHOTOGRAPH 7—showing Cruiser's foremast.

- 1.—*WC type 293* aerial with waveguide mouth (A) and "cheese" type parabolic reflector (B).
- 2.—Associated directional interrogator type 242.

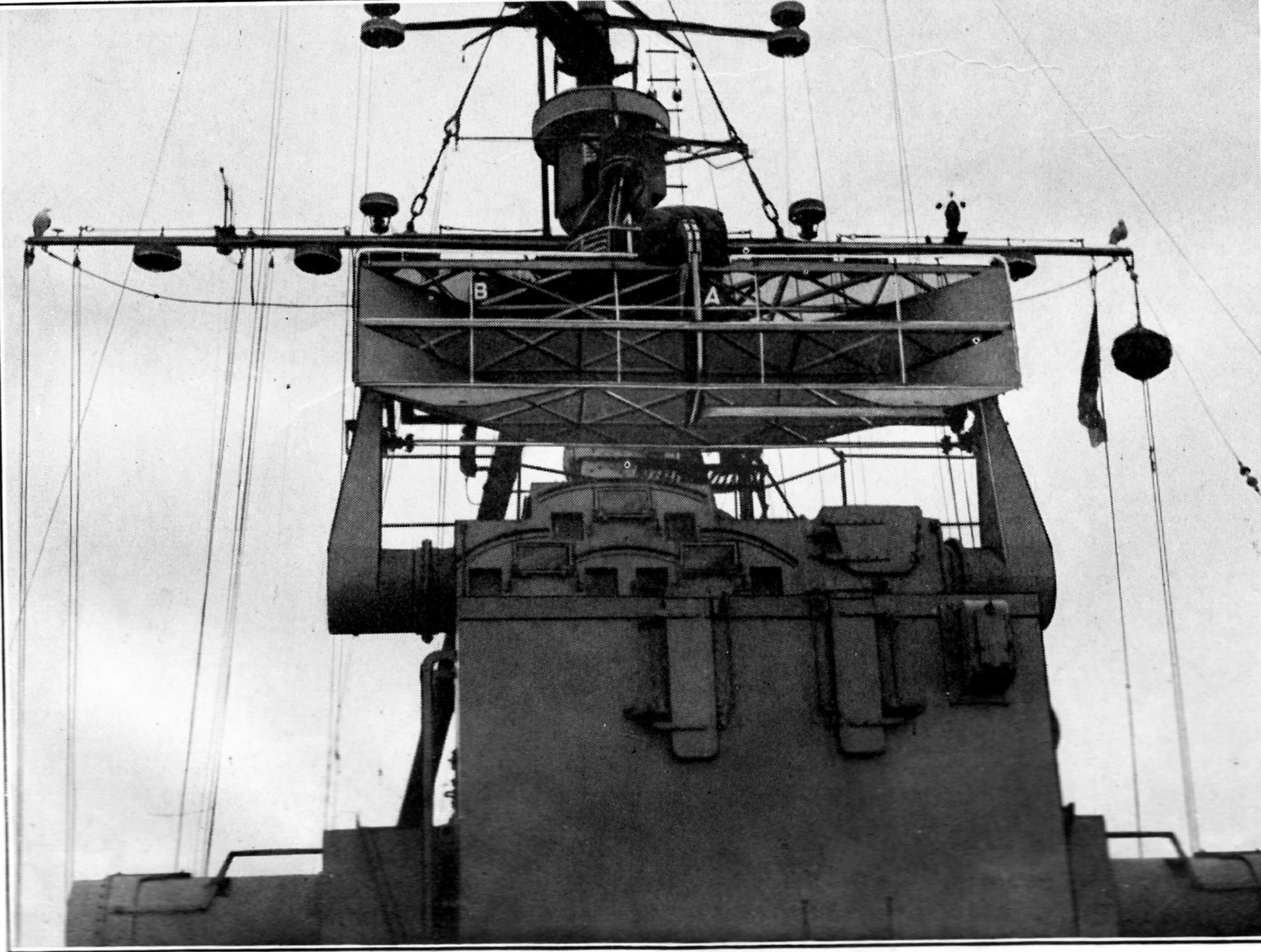


PHOTOGRAPH 9—Mast of “ Fairmile ” Class M.L., showing :—

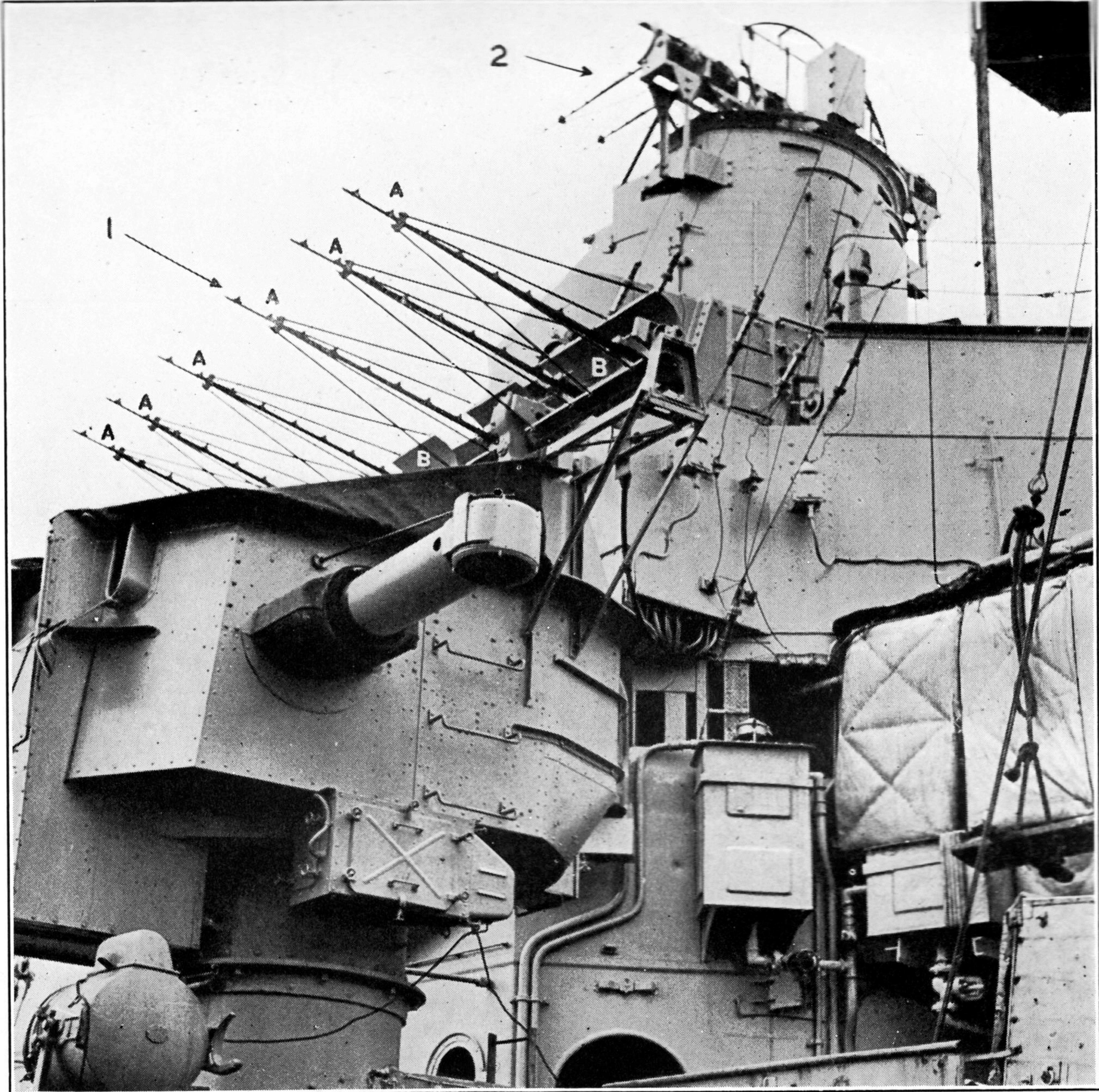
- 1.—W.S. type 268.
- 2.—Interrogator type 242.
- 3.—I.F.F. type 253.

(Inset)

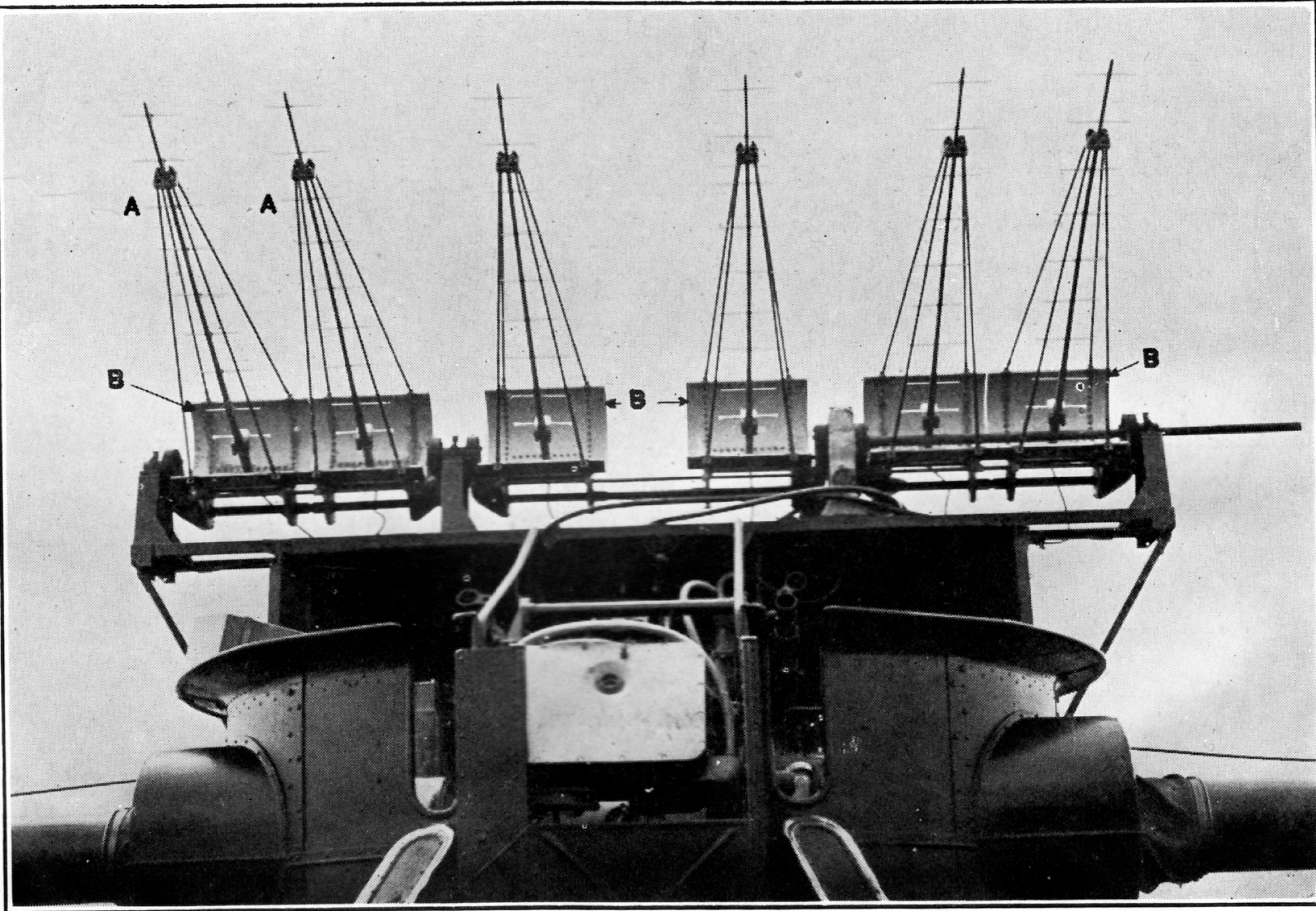
PHOTOGRAPH 8—3-centimetre surface warning aerial of W.C. type 267 w showing waveguide mouth (A) and exposed “cheese” type parabolic reflector (B).



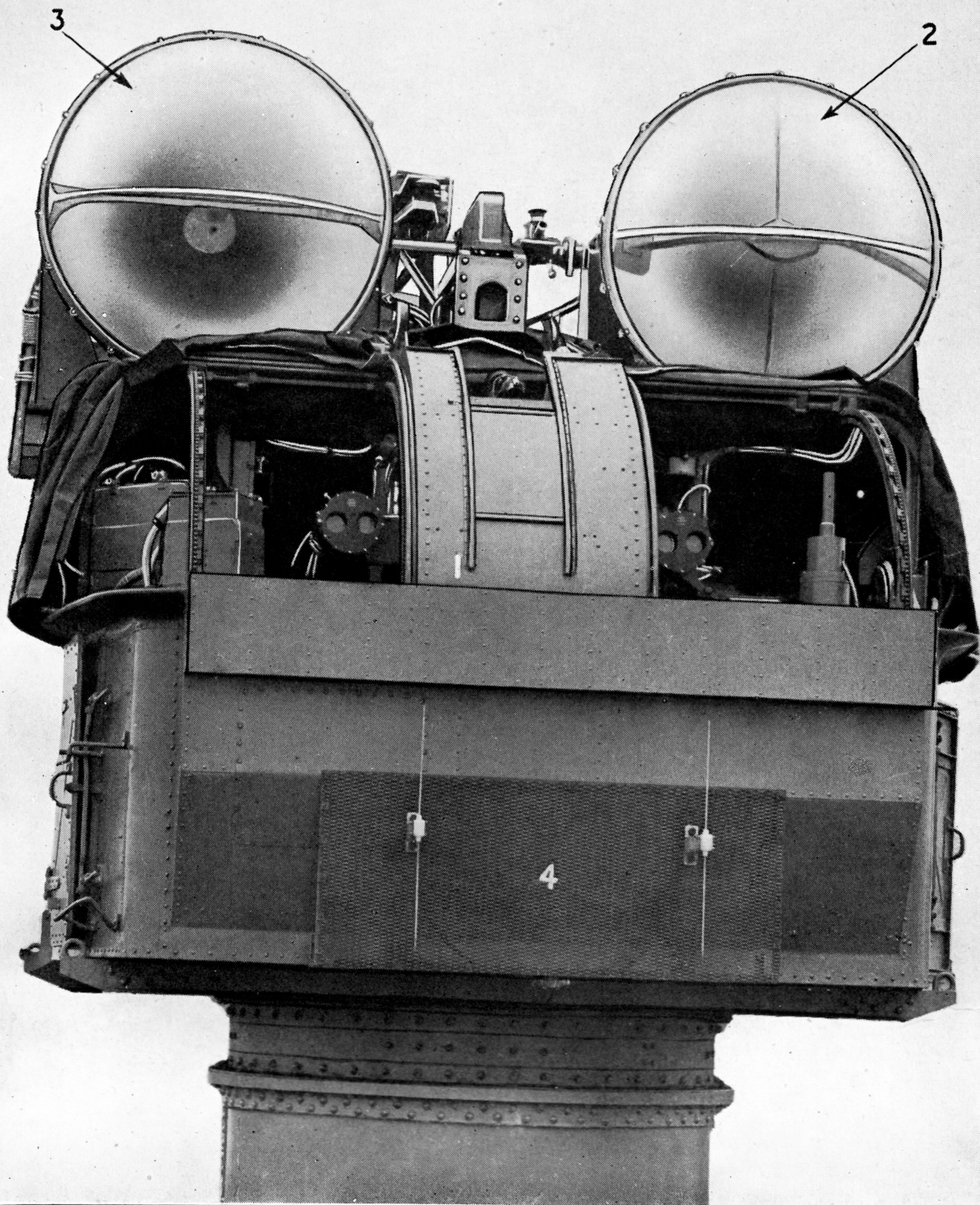
PHOTOGRAPH 10—Showing *G.S. type 274* aerial system including transmitting and receiving waveguide mouths (A) and “ cheese ” type parabolic reflectors (B).



PHOTOGRAPH 11—Cruiser's superstructure showing (1) *GA type 285* on H.A. Director with "fishbone" type aerials (A, A, etc.) and "pig-trough" type reflectors (B, B) *GS type 284* (with aerial ASG) is seen behind (2).

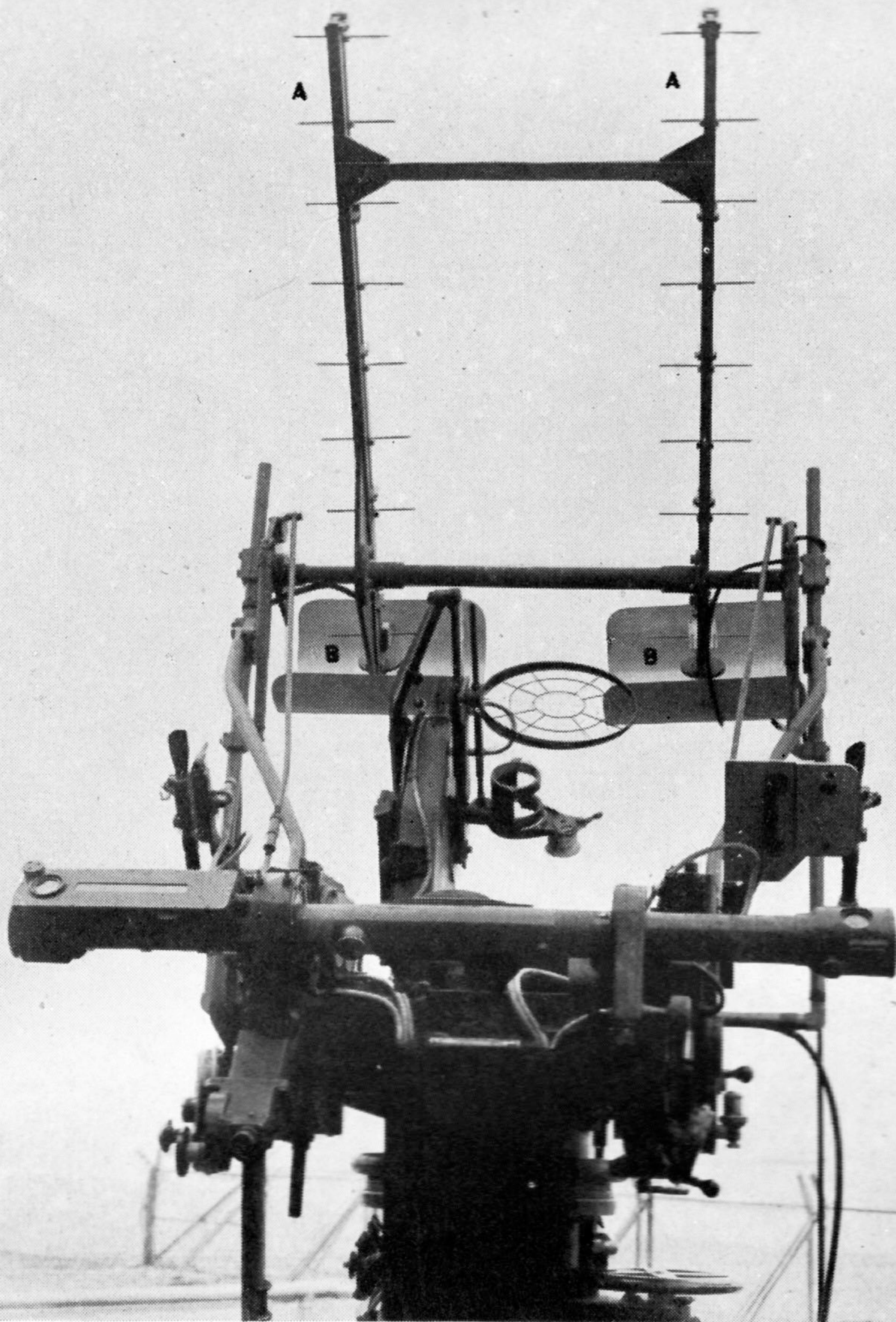


PHOTOGRAPH 12—Another view of *GA type 285* on H.A. Director showing “fishbone” type aerials (A, A, etc.) and “pig-trough” type reflectors (B, B, etc.).

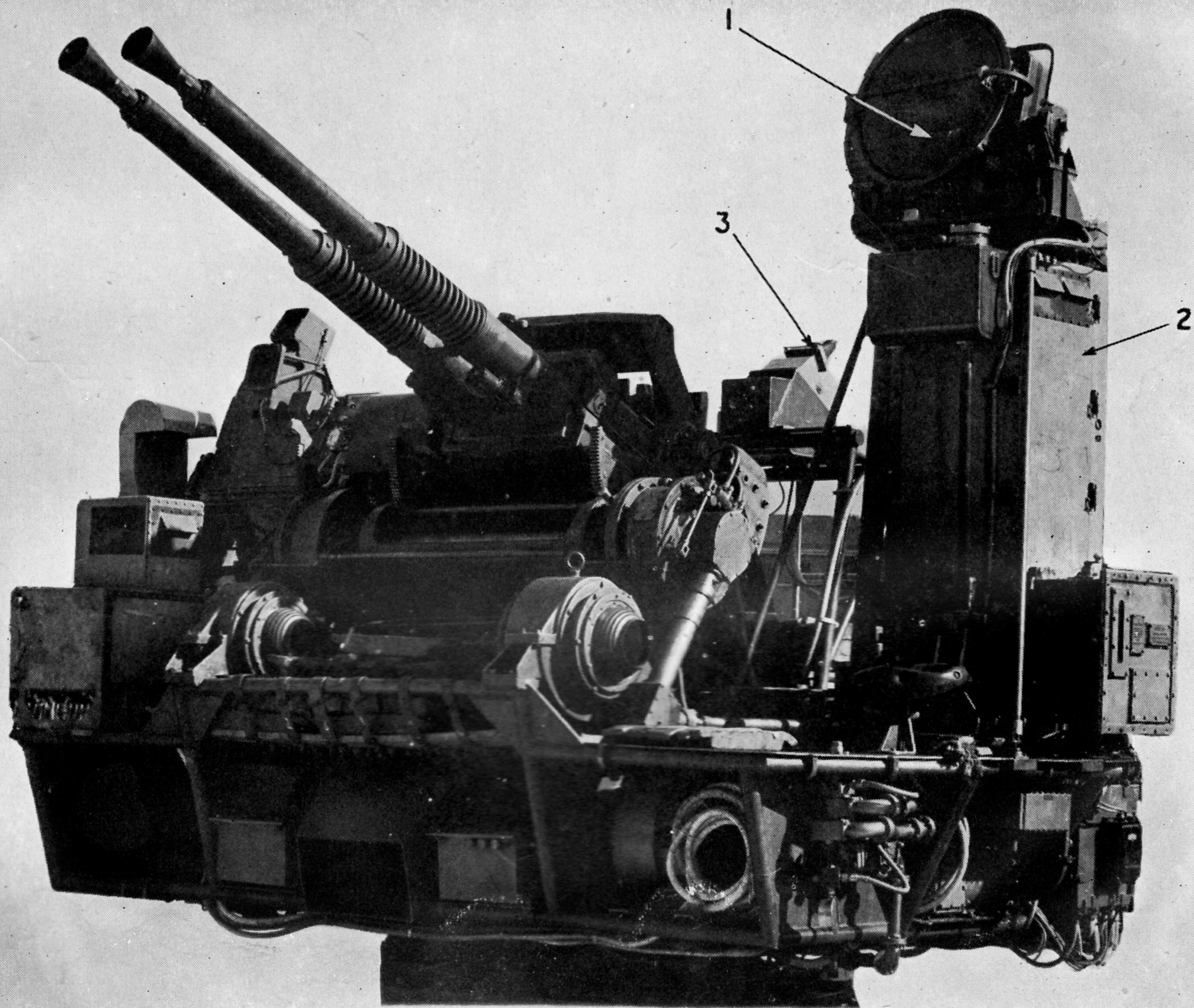


PHOTOGRAPH 13—*GA type 275* showing :—

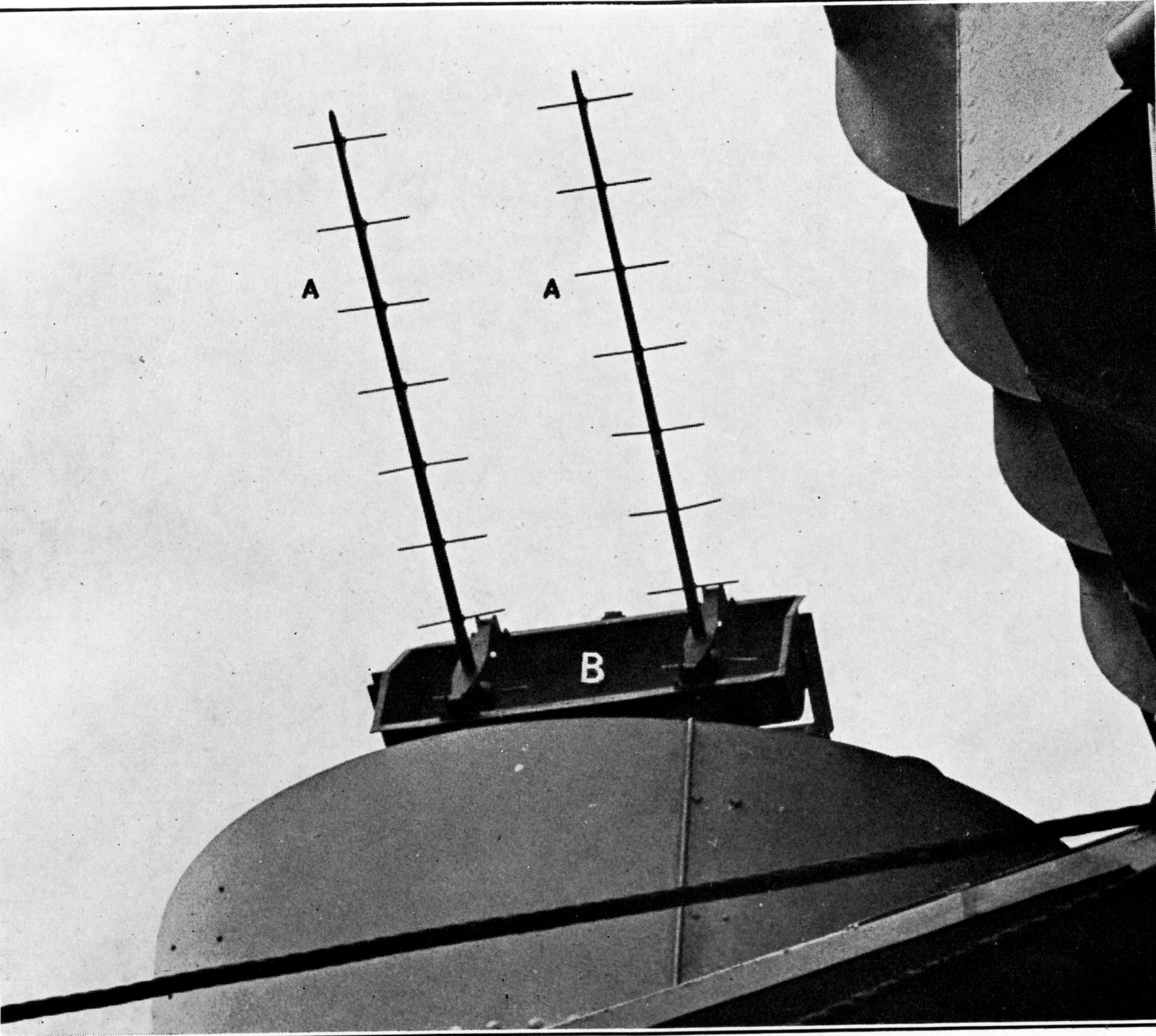
- 1.—Director (non-standard).
- 2.—Receiver nacelle.
- 3.—Transmitter nacelle.
- 4.—Interrogator aerials and reflector.



PHOTOGRAPH 14—GC type 282 mounted on Pom-Pom Director and showing "fishbone" type aerials (A, A) and "pig-trough" type reflectors (B, B).



PHOTOGRAPH 15—GC type 262 on S.T.A.A.G. mounting showing
1.—Scanning aerial mirror.
2.—Radar operator's control panel.
3.—Control officer's remote radar display.



PHOTOGRAPH 16—*GB type 283* mounted on Barrage Director.

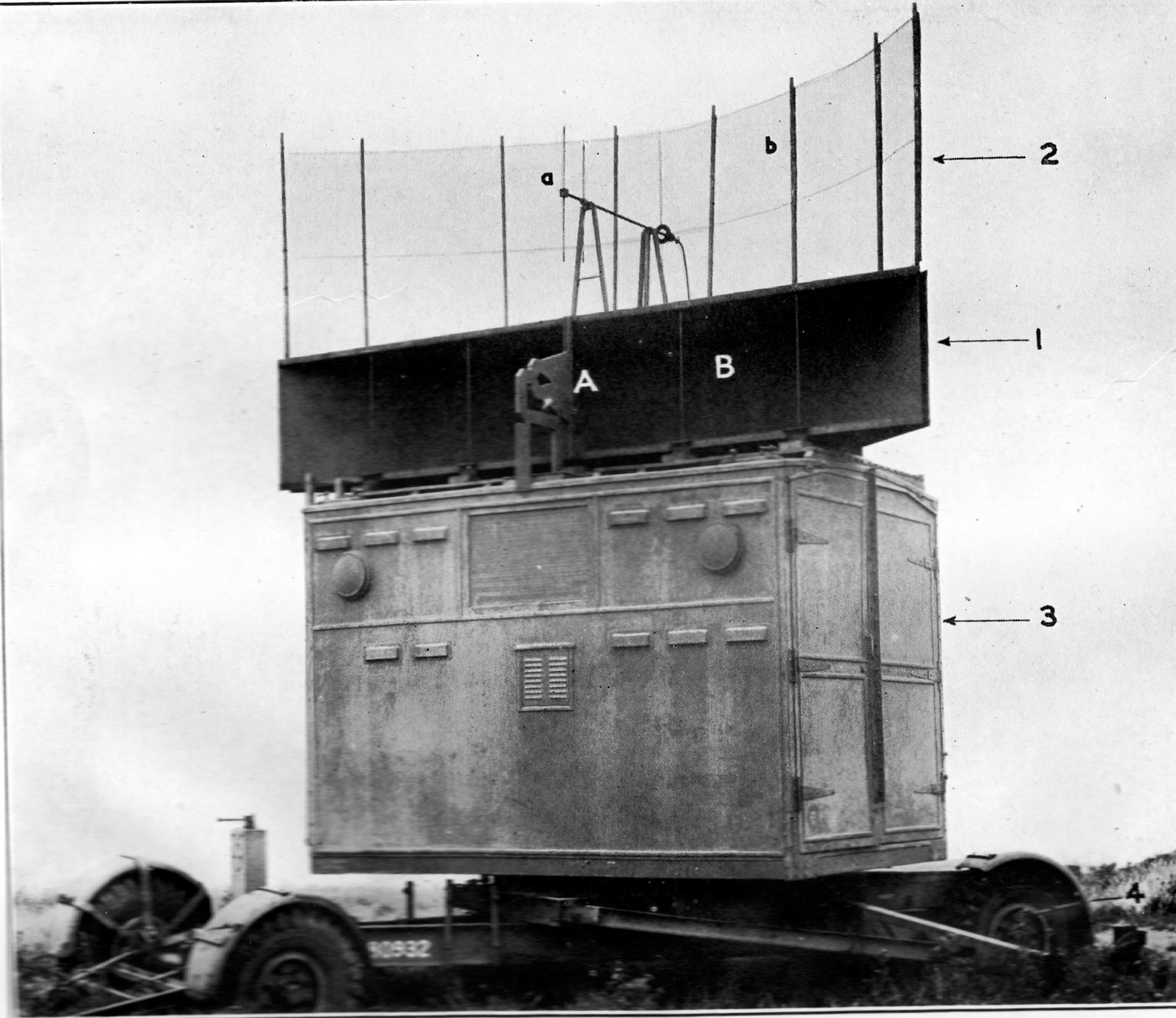
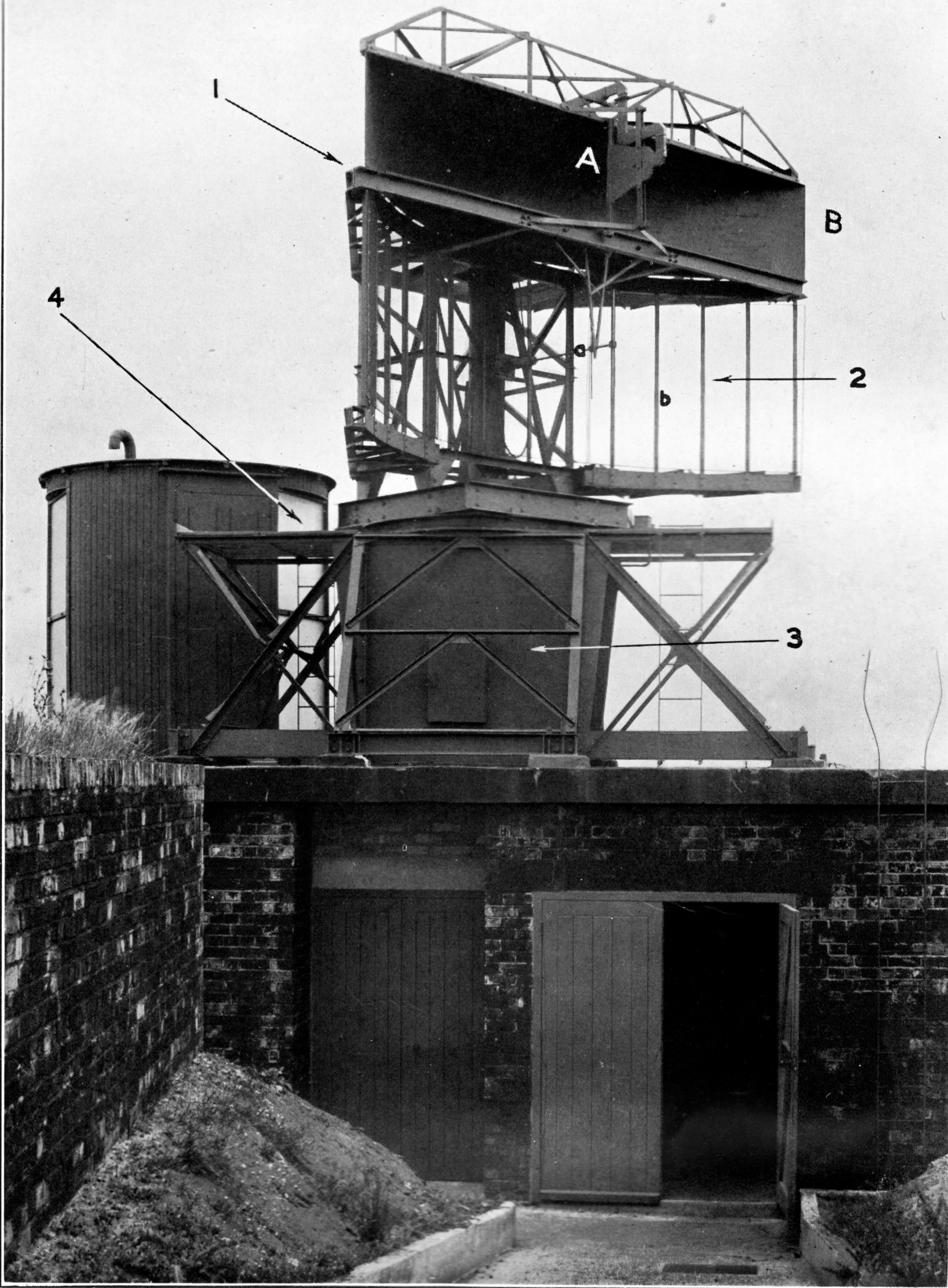


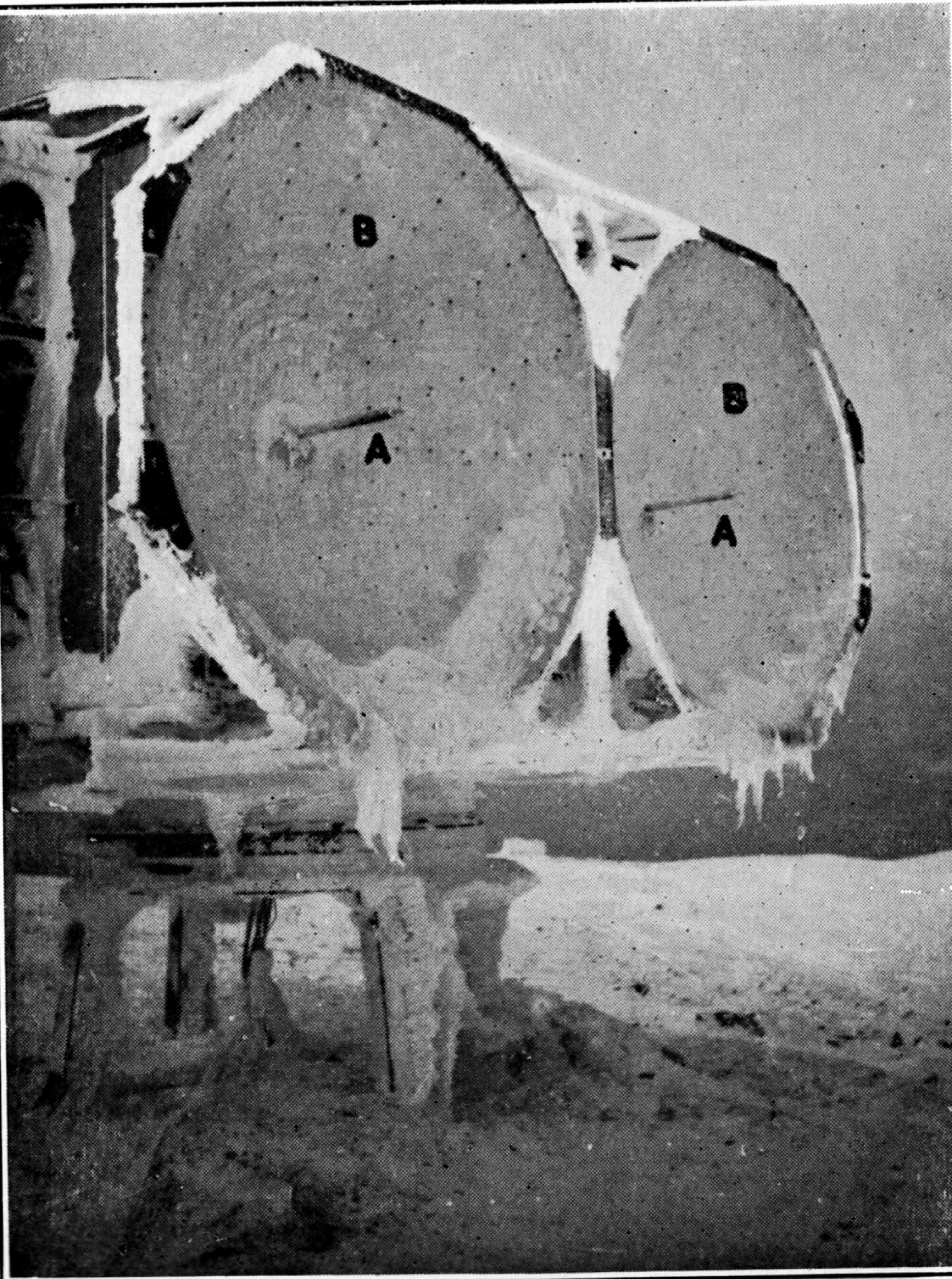
FIGURE 17—Shore trailer set type TTT showing—

- 1.—Location aerial system (A-waveguide mouth, B- "cheese" type reflector).
- 2.—Interrogator (a-aerial, b-reflector).
- 3.—Rotatable cabin containing transmitters and receivers.
- 4.—Trailer.



PHOTOGRAPH 18—Shore radar sets showing—

- 1.—*Type 277S* (A—waveguide mouth, B—"cheese" type parabolic reflector).
- 2.—Directional Interrogator. (a—aerial, b—reflector).
- 3.—Cabin containing turning gear for 1 and 2.
- 4.—*Type 273QS* (aerial and reflector inside parabolic lantern).



PHOTOGRAPH 19—Shore station (*type 273QS* with exposed aerials) at Saebol, Iceland.

CHAPTER I

INTRODUCTION AND SUMMARY

This book describes the many uses of radar and is written primarily for the non-technical officer, particularly in cases where he has no specialist or qualified radar officer to advise him.

2. Radar now has such universal application that it is necessary for general service officers to know as much about it as the older established subjects, such as gunnery and navigation, of which it now forms an integral part.

3. In the early days of radar, technical officers had necessarily to play a large part in its operational use. While their technical advice will always be necessary it is very important that the development and control of the *use* of radar should come from those at sea whom it serves and who are in the best position to judge its value and state new requirements. Indeed, it will be dangerous to leave this function solely to technical officers if we are to get the best out of our superior radar equipment and keep ahead of the enemy.

4. Constant training is of great importance. An old radar set used well is always better than a more modern set used badly. Attention must therefore be directed towards getting the best out of equipment actually fitted, rather than on optimistic hopes of the performance of forthcoming gear; the latter is in any case unlikely to give its designed results for some time after arrival.

5. In planning and in the execution of every operation, the influence of radar must now be kept constantly in mind, as must also effect of the use of radar or counter-measures by the enemy.

SUMMARY OF CONTENTS

6. The following is a brief summary of the contents of this book. It should be explained that the Chapters in Part II do not set out to be a detailed description of the various uses of radar; detailed use is contained in the various specialist publications listed in *Table I*. This book is intended rather as a general introduction to the subject, and the various chapters are written as far as possible self-contained, which accounts for a certain amount of duplication.

7. **Part I** contains a description of *how radar works, what it can do and what it cannot do, details of the various types of radar, and the typical radar equipment of ships.*

CHAPTER II

8. Radar is no longer black magic, and it is perfectly easy for the average officer to understand enough about it to realise its capabilities and limitations. Two points particularly worth studying are:—

- (a) the coverage given by different types of radar in the ship.
- (b) the correct manipulation of remote display (P.P.I.) which is now commonly fitted outside the radar office, *e.g.* in the A.I.C., and therefore is not necessarily operated by radar personnel.

CHAPTER III

9. It is necessary for officers to know the *performance* to be expected against various targets from the radar in their ships for two reasons:—

- (a) so that they will appreciate the extent of warning that should be received and the range at which "blind" fire is likely to be effective. This is analogous to knowing the range of the guns or torpedoes themselves.

APPENDIX I

- (b) because performance is the acid test of technical efficiency: if the performance given in *Chapter III* and in more detail in *Appendix I* is not being achieved, special steps should be taken to find the cause.

CHAPTER V

10. Besides knowing radar's capabilities, it is very necessary to appreciate its *limitations* such as inability to detect objects under water or at very close range, the effect of gaps in the vertical coverage diagram of aircraft warning sets, and the confusion that may be caused by false echoes.

11. **Part II** is the primary object of this book (though it cannot be fully understood without a study of *Part I*), and describes the many *uses of radar.*

CHAPTER VI

12. The *Action Information Organisation* is the nerve centre which controls the operation of radar in a ship, receives radar reports, and, after filtering them and collating them with other intelligence, passes the result to the Command.

- CHAPTER VII 13. Surface warning radar has not altered the principles of *tactics* but it has considerably altered the technique of such operations as reconnaissance, search, patrol, shadowing, and "weapon tactics." The formation of ships in column must now receive special consideration, in order to avoid disclosing their disposition to the enemy and becoming a target for accurate blind gunfire.
14. With the advance in technique of surface warning and gunnery radar, night actions of the future may be fought at day ranges and indeed have already been fought at considerable range.
- CHAPTER VIII 15. A special application of surface warning radar is its use in *A/S warfare* where detection ranges are relatively small and great alertness is required.
- CHAPTER IX 16. *Navigation* receives great assistance from radar, particularly from P.P.I. display which "charts" the coastline, and from other radio devices such as Radar Beacons and Loran. The snags of these devices must be learnt, as well as their capabilities, if they are to be used with confidence as aids to navigation.
- CHAPTER X
CHAPTER XI 17. *Aircraft warning radar* besides enabling general defensive measures to be taken, makes possible *fighter direction* and at a later stage *target indication* for the armament against those attackers who have penetrated the fighter defences. The use of several radar sets, properly controlled, is necessary for complete cover.
- CHAPTER XII 18. Radar is now an integral part of *gunnery fire control*, and the radar panels are usually fitted in the various fire control rooms so that radar range, bearing, and spotting are available near the fire control table. Besides overcoming many of the former weaknesses in fire control such as inaccurate range and uneven rate, radar now makes blind fire practicable up to considerable ranges.
- CHAPTER XIII 19. *Torpedo control* is also assisted by radar. Even if blind fire is not used, radar enables the torpedo armament to be brought to such a degree of readiness that fire can be opened as soon as the enemy is sighted. Although radar does not replace the *searchlight*, it reduces the necessity for large numbers of searchlights and helps in their control.
- CHAPTER XIV 20. An inherent weakness of radar is its inability to distinguish at once and with certainty between friendly and hostile targets. The *radar recognition system* (Interrogation and I.F.F.) helps to overcome this limitation and is at present the safest method of recognition. Officers should know the rules for the use of I.F.F. and its codes in the same way that they are acquainted with visual recognition systems.
- CHAPTER XV 21. *Radio and non-radio counter-measures* are used by the enemy or ourselves to spoil the other side's radar, and are likely to come into increasing prominence as the attainments of radar approach a foreseeable limit. Alternatively, the side which lags behind in radar development is likely to concentrate on counter-measures as a quick cheap method of restoring the tactical balance. *Anti-jamming measures* are the antidote to counter-measures, and a race between them may ensue like that between armour and the gun.
- CHAPTER XVI 22. *Shore radar* though normally the responsibility of another service is often of interest and value to the navy, particularly in the defence of fleet anchorages and shipping off beaches during an assault operation. It has also been used with effect offensively to direct small craft attacking enemy shipping.
- CHAPTER XVII 23. *Combined operations* have become increasingly dependent upon radar and other radio aids, particularly in the requirement for reliable and accurate location of the objective. The defence of large numbers of lightly armed vessels and craft under difficult conditions presents some special radar problems.
- CHAPTER XVIII 24. *Radar in aircraft* enables them to cover an area of search more efficiently and quickly, particularly in poor visibility, and so make full use of their mobility. It also makes practicable synchronised attacks in poor visibility and by night.

25. **Part III** deals with the **employment of radar** at sea, and its *organisation and control* in a unit in order to achieve reliable cover. This will call for considerable skill in the case of air cover if the density of targets is high.

CHAPTER XIX

26. The *Radar Policy* to be adopted must be a balance between the considerable advantages which radar confers and the possibility and consequences of disclosing the unit's presence. Knowledge of the skill and extent of the enemy's interception and D/F ("Y") services will play a large part in the decision. It is important, however, not to attach too much weight to problematical dangers of interception, and a good rule is "when in doubt, use radar." Radar should *always* be used when action is imminent.

CHAPTER XX

27. *In harbour*, full opportunity should be taken for rest, maintenance, and training; but where the shore radar cover is insufficient it may be necessary for ships to provide or augment it.

28. **Part IV** deals with a number of miscellaneous though important subjects.

CHAPTERS XXI AND XXII

29. The *personnel and training* aspects of radar should be given careful attention. Training and exercises must include not only the "man behind the tube" but also those in associated compartments such as the Operations Room, A.D.R., and Fire Control rooms. The recent formation of the R.C.-R.P. branch should facilitate this, since ratings are interchangeable within their own spheres; but it must be remembered that ratings coming to sea will have received only basic training and must acquire their skill and experience at sea.

30. *Maintenance* is probably the most important aspect of radar at the present time, as the complexity of modern radar equipment is tending to outstrip the resources available to keep it working efficiently. Any assistance that can be given to maintenance staffs will therefore be amply repaid by results. If it is necessary to employ technical officers or ratings on other duties, the price is likely to be inefficient radar.

31. The degrees of *security* attached to radar has now been relaxed and equipment actually in service is rated no higher than "Confidential," or even "Restricted" in the case of some older sets. The same applies to literature about radar, e.g. this book is "confidential" though its predecessor was "secret." There is clearly everything to be gained by encouraging discussion of radar and its uses within the service, though this must not of course be carried outside the service, nor should radar matters be discussed with the Press.

CHAPTER XXIII

32. Correct *radar drill* or "Operating Procedure" both by operators and by controlling officers must be insisted upon. Incorrect or slack orders will lead to poor operating and inaccurate and misleading reports.

CHAPTER XXIV

33. It is the duty of ships to provide full *reports* about the use and technical efficiency of radar, particularly in action. Without such reports, it is impossible to disseminate radar information, nor to guide future development along the right lines. New ideas and suggestions from sea are always welcome and always read, even though it is not always possible to act on them, for example because of their limited application or the large numbers of other radar requirements.

LOCAL ORDERS

34. Commanders-in-chief will issue in Fleet or Station Orders any amplification required to the contents of this book. This applies particularly to Part III, portions of which are framed as instructions; these are, of course, subject to local acceptance or modification.

RADAR GUARDBOOKS

35. Owing to the speed with which radar is developing, it is not practicable to keep a book such as this one always up-to-date. Further, there is often information, such as intelligence of enemy "Y" or counter-measures, which for a time must remain secret, yet requires to be readily accessible. To meet these requirements, it is recommended that a system of secret radar guardbooks should be employed on each station. These guardbooks could also contain copies of relevant Admiralty "A" messages and station messages concerning radar.

CHAPTER II

HOW RADAR WORKS

Note. This Chapter should be read in conjunction with *Chapter V* which describes the limitations of radar, and *Chapter III* which gives its capabilities in greater details.

WHAT IS RADAR?

1. Radar is a system which uses the **reflection** of wireless waves in order to locate ships, aircraft and land, irrespective of the visibility. In nearly all cases radar gives both *Range* and *Direction*—hence the name—and consequently the precise relative position of the object located. High aircraft can be located up to a range of over a hundred miles, and large surface objects up to ranges which equal or exceed the best visibility.

2. A radar set sends out a stream of short pulses of radio energy. These strike objects in their path and are reflected back as "echoes" and picked up by the radar receiver. Since radio pulses travel at a known constant speed (the speed of light), the time taken for a pulse to go out and return represents the **range** of the located object. This time is, of course, exceedingly small, but it can be measured electrically and shown as a range on a suitable radar display, such as the cathode ray tube "A" display shown below. A steady picture is ensured by the rapidity with which the pulses follow one another (*cf.* the Cinema). In addition, the surface of some tubes is made of retentive material giving "after-glow" which makes it easier to see small fluctuating echoes.

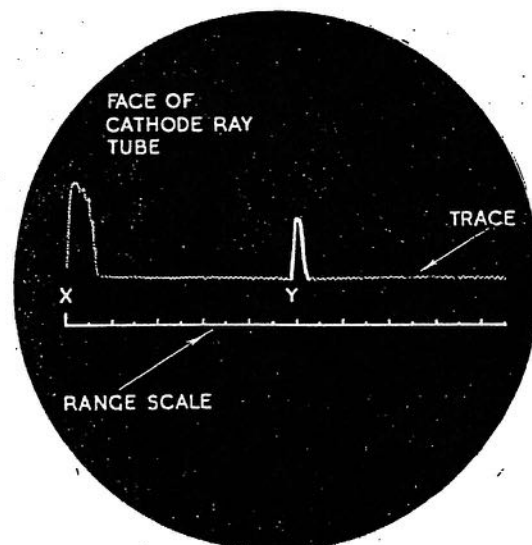


Fig. 1—"A" Display. X represents zero range, *i.e.* the position of own ship. Y is the echo of an object on the bearing of the radar aerial. XY is the range of the object which can be read off the scale underneath the trace.

3. In order to get the **direction** of the object the transmitted energy is focussed into a beam which can be pointed in any chosen direction. This beam is obtained by using a specially designed aerial.

4. The general arrangement of a radar set is shown in Fig. 2 :—

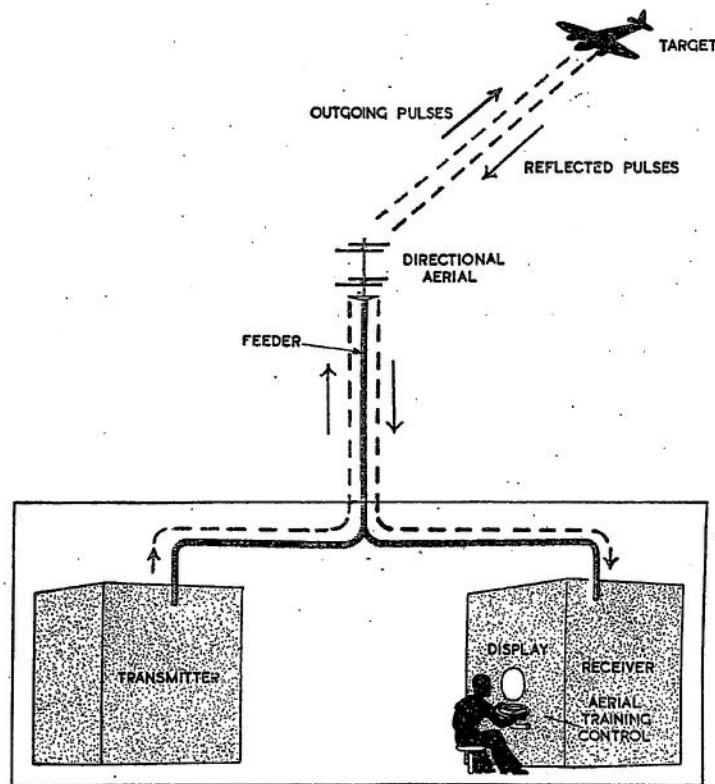


Fig. 2—Simplified diagram showing how radar works. The outgoing pulses are generated in the transmitter and fed to the aerial, which directs them at the target. The reflected pulses ("echoes") are picked up again by the aerial, fed down to the receiver, and shown on the radar display.

5. There are two analogies with radar which may be found helpful :—

(a) *Sound.* A man shouting near a cliff hears the echo of his voice and by the time interval he can gauge its distance, or even measure it if he has a stop watch. The louder he shouts, the further away can he receive echoes (in radar, increasing the power increases the range obtainable). If a megaphone is used, not only is a greater "range" obtainable, but a sense of direction is introduced; this corresponds to the directional aerial in radar.

(b) *Asdics.* Everyone is familiar with the A/S system of underwater detection which consists of sending out supersonic wave pulses in a given direction, by training the oscillator, and recording the echo in terms of range on an A/S recorder. The oscillator corresponds to the radar aerial, and the recorder to the radar display.

WAVELENGTHS AND AERIALS USED IN RADAR

6. It is assumed that the reader has a rough knowledge of wireless as it is used for broadcasting and communications. Though fundamentally the same, radar uses wavelengths considerably shorter. This is for two main reasons :—

(a) The most efficient aerial is one whose length corresponds to the wavelength used, since it will then resonate electrically. As there is a severe limit to the size of aerial that can be mounted in a ship, a short wavelength must be used for efficient results. In practice half-wavelengths aerials ("dipoles") or their equivalent are used in ships; by this means a high proportion of the transmitter's energy is made to take the air.

(b) In order to get the focussing of energy required to obtain direction and greatest possible range, it is also necessary to have a **reflector** behind the aerial. Sometimes there are several aerials and several reflectors, constituting an "aerial array." Once again the space limitations in a ship are such that small aerials and reflectors, and therefore short wavelengths, must be used.

7. There is no such thing as a "general-purpose" radar, at least not an efficient one. Each set is designed for a special purpose and requires a particular shape of radar "beam" to do its job. For this reason we employ several distinct categories of "short" wavelengths in radar:—

(a) *Metric sets* (WA and certain WC sets) using wavelengths of 7, 3 or $1\frac{1}{2}$ metres which are used for rough and ready warning where a floodlight effect is required.

(b) *Decimetric sets* using a wavelength of $\frac{1}{2}$ metre (50 centimetres) which enables the energy to be concentrated into a narrower beam. Such sets are used for gunnery ranging (GS, GA, GC and GB) where maximum range in one direction and greater precision of bearing are required.

(c) *Centimetric sets* (sometimes called microwave sets) using a wavelength of 10 centimetres or less which enables a still sharper beam to be obtained. Centimetric wavelengths are used for surface warning and low aircraft warning cover (WS sets), and for the latest gunnery ranging sets (GS, GA and GC). Centimetric wavelengths are also used in certain modern WC sets where short or medium range air and surface warning is required for target indication, as explained in *paragraph 24*.

COVERAGE DIAGRAMS

8. With the radar aerial trained in any one direction there is an area in both the horizontal and vertical plane within which a target of given size will be detected. This area is called the horizontal or vertical "Coverage Diagram" (or sometimes the "Polar Diagram") of a set. It is important to study the typical coverage diagrams of various types of radar as they represent the extent and reliability of warning that can be expected.

Horizontal Coverage Diagrams. Side echoes and back echoes

9. Horizontal coverage diagrams are quite straightforward. It will be clear from what has been said before that the shorter the wavelength, the narrower can be made the beam in a horizontal plane. Typical horizontal coverage diagrams are shown in *Fig. 3*.

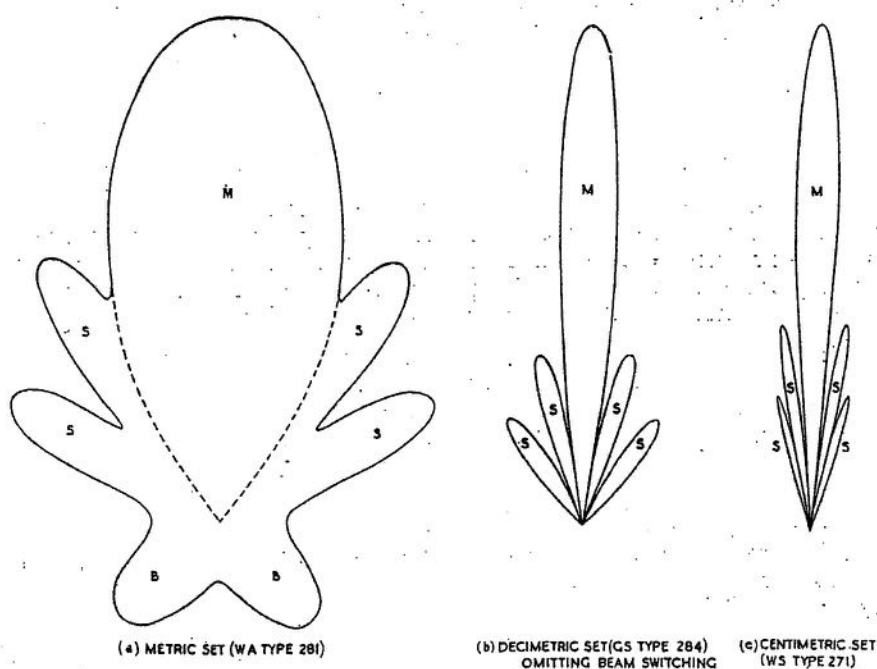


Fig. 3—Horizontal Coverage diagrams for typical metric, decimetric, and centimetric radar sets.

M—main lobe.

S, S—Side lobes (in the case of decimetric and centimetric sets there may be additional smaller side lobes).

B, B—Back lobes (decimetric sets may have small back lobes; centimetric sets have practically none).

The above diagrams are NOT to relative scale as regards range, *i.e.* the range of a WA set against high aircraft is much greater than that of a GS or WS set against surface targets. Also, the actual extent of the coverage diagram depends upon the size and inclination of the target.

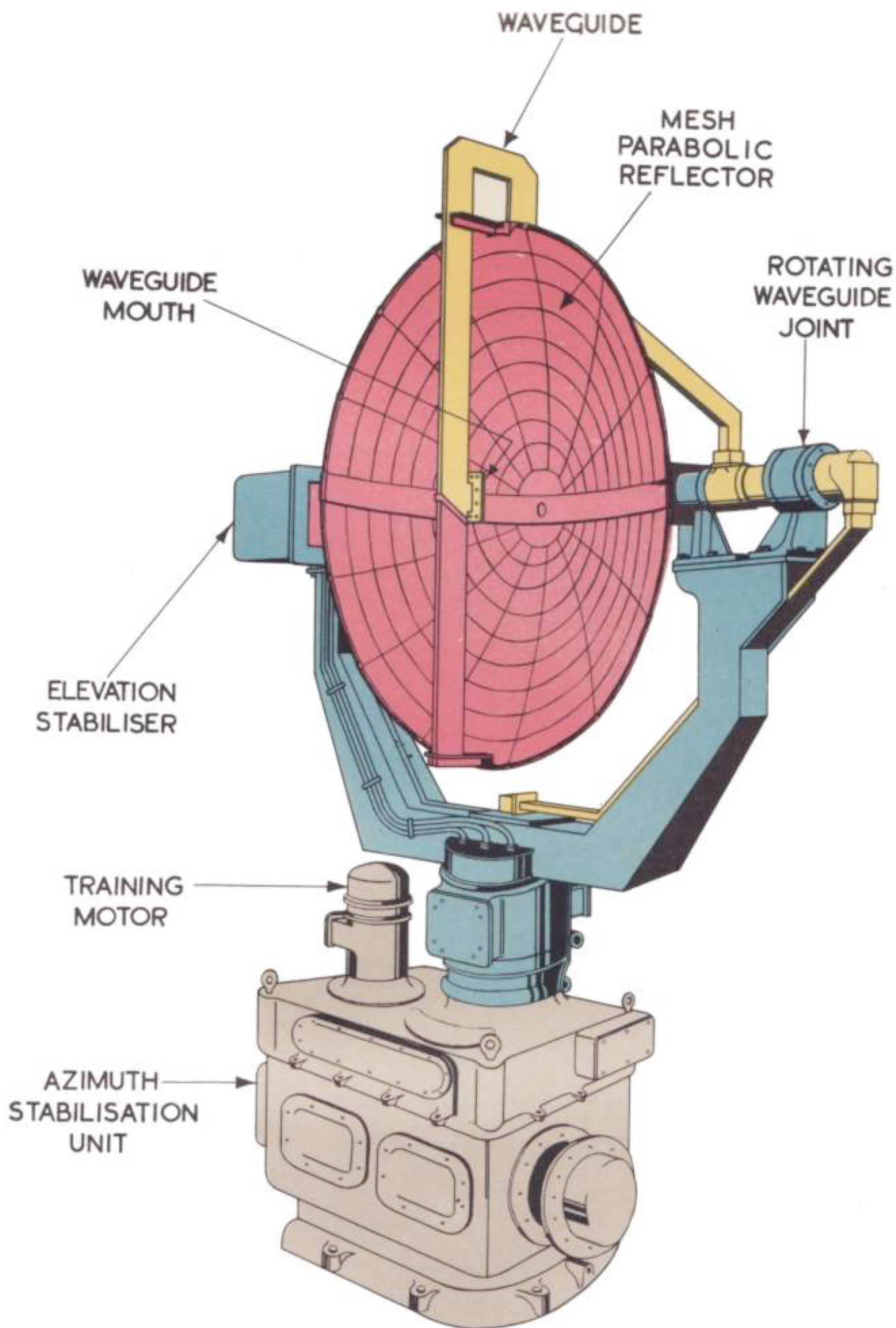


Fig. 4

AERIAL SYSTEM (AUK) OF CENTIMETRIC RADAR SET

WS Type 277

10. In each of the above diagrams "M" represents the main beam or lobe, within which objects of a given size will be located with the radar aerial pointing in a given direction. The actual extent and width of the cover in miles will depend upon the size of the target as well as the type of radar set, but the general shape of the coverage diagram will remain the same for each type of set.

11. Unfortunately the main beam "M" is not the only one transmitted. This is because the reflector used to focus the beam is seldom 100% efficient. In metric sets the reflector consists only of a number of dipole rods placed behind the aerial (see *Photographs 1, 2 and 3*), so that a certain amount of the radar transmission escapes in the reverse direction giving rise to back lobes (B, B) which result in *back echoes* up to short ranges.

12. Similarly, some of the energy escapes at an angle to the main beam giving rise to side lobes (S, S) which result in *side echoes*. Thus, in *Fig. 3a*, an object at short range on a bearing of 070° , might well be detected when the main lobe was pointing 000° . This of course is very confusing, but it should be noted that the side echoes occur at equal angles either side of the main echo and this is how they are usually spotted as such.

13. In decimetric sets, more complicated aeriels and more efficient reflectors of the pig-trough type are used (see *Photographs 8 to 11*). The result is that little energy escapes backwards and side lobes are much reduced.

14. In centimetric sets the wavelength is so short that a parabolic reflector can be used. The aerial is placed at the focus of the reflector, rather like a fire side radiator and besides giving better concentration of the main beam, side echoes are still further reduced, while back echoes are practically eliminated. Typical parabolic reflectors are shown in *Fig. 4* and *Photographs 4 to 7* and *12 to 15*. In some sets a complete "dish" or "mirror" is used; in others the reflector consists of a "cheese" or slice of a full dish.

15. It is of interest to note here that in modern centimetric radar sets an aerial, as we normally know it, is not used at all. The radar energy is fed up a "wave-guide," instead of a wire feeder, and the mouth of the wave-guide is placed at the focus of the reflector, *i.e.* at the point where the dipole aerial would otherwise have been. The energy is thus "sprayed" into the reflector, which focusses it and sends it out in a beam.

This is shown in *Fig. 4*. The dimensions of the cross section of the wave-guide correspond to the wavelength.

Vertical Coverage Diagrams

16. Vertical coverage diagrams are not quite so straightforward. If the radar aerial was elevated so as to be pointing well clear of the sea, we should get a result (called a "free-space" diagram), as in *Fig. 5*. Such a system is in fact used in certain sets for heightfinding, as described in *Chapter XI*.

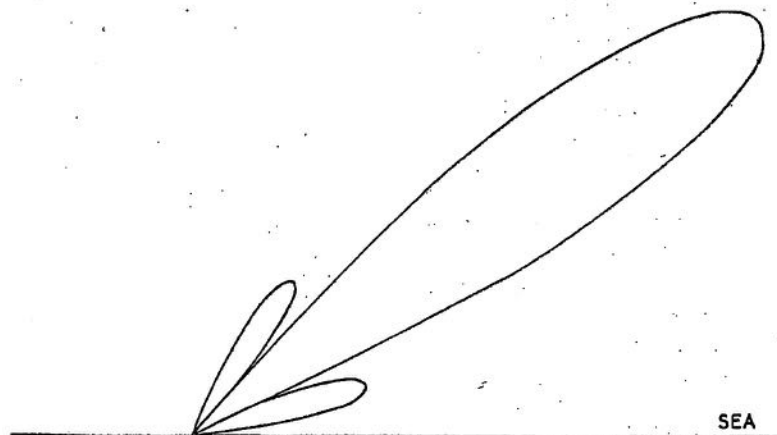


Fig. 5—Radar beam elevated clear of sea, showing "free-space" diagram.

17. If, however, the radar aerial is layed on the horizon, as is usually the case, the shape of the beam and therefore the vertical coverage diagram get changed very considerably due to reflection off the sea. The reason for this is clear from the *Fig. 6* :—

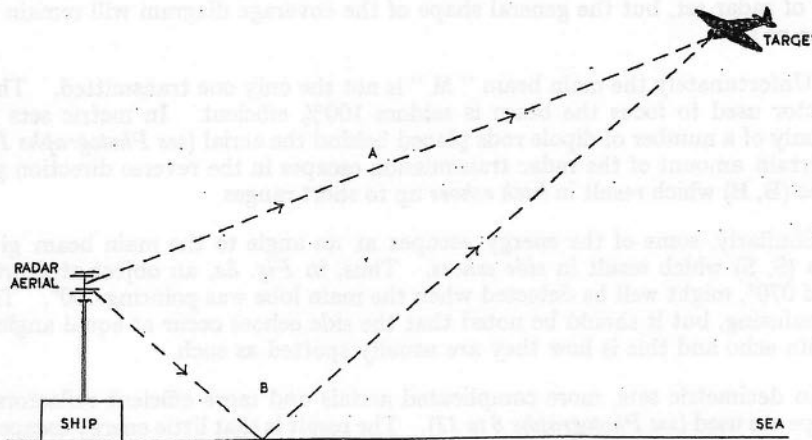
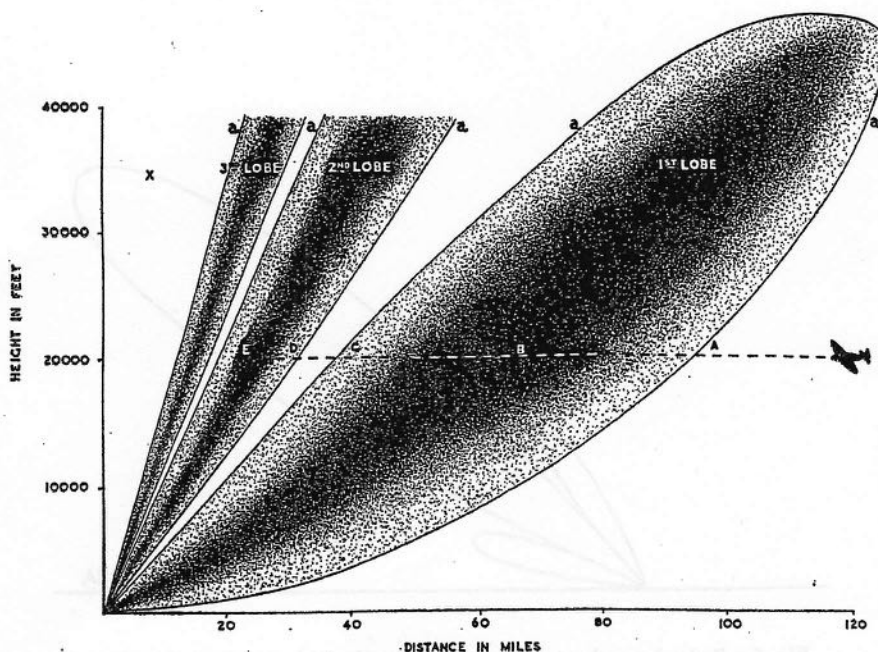


Fig. 6—Effect of sea reflection on radar beam, vide paragraph 17.

It will be seen that radar pulses arrive at the target by two simultaneous routes, one direct and one via the surface of the sea, which acts as a nearly perfect reflector. These routes differ in length, and it may be that pulse B will have the effect of completely cancelling pulse A so that no echo will be received back. In another relative position of the target the effects of pulses A and B may act in unison, and a strong echo will be received back. In intermediate relative positions of the target the strength of echo received back will be somewhere in between.

18. This means that a kind of wave pattern is formed, as in *Fig. 7*.

Fig. 7—Pattern of typical vertical coverage diagram (WA type 279), showing the variation of intensity within the lobes caused by sea reflection. The lines a, a, indicate the limits of the areas within which detection is possible. The numerous narrow lobes and gaps in the region X are not shown.



19. *Aircraft Detection.* Referring to *Fig. 7*, an aircraft target approaching will first be detected weakly at point A. The echo will rise to a maximum at B, and then fall away again in strength. Between the first and second lobes, *i.e.* from C to D, there will be a minimum or "gap" and no echo will be received. From D to E the echo will rise again to a maximum.

20. This pattern due to sea reflection is a nuisance because it means that a metric radar set cannot give continuous radar cover since there will always be gaps between the lobes where an aircraft cannot be detected. If the target is very lucky he may even fly down a gap and not be detected at all. The only relieving feature is that use can be made of the wave pattern to estimate height. A fuller description of the effect of vertical coverage diagrams on aircraft warning, and their use for heightfinding, is contained in *Chapters 10 and 11*.

21. *Surface detection.* The lowest part of the first lobe is used for detection of ships and land, and it will be seen that it gradually rises. This partly explains why a large ship is usually detected at greater range than a small one, though in modern centimetric WS sets the power and concentration of the beam is such that the actual optical horizon between own ship's radar aerial and the top of the target ship's superstructure is normally the limiting factor, and not the rise of the lobe.

22. *Typical vertical coverage diagrams.* In *Fig. 7* which is the vertical coverage diagram for WA type 279 the lines aa join the points within which the strength of echo is sufficient for reliable detection of a target of given size, which for aircraft warning is generally taken as a medium bomber or two fighters. Vertical coverage diagrams are usually indicated by these exterior lines alone, but it is important to remember that the echo strength within the lines is not constant. Typical vertical coverage diagrams for other metric sets are shown in *Fig. 8*.

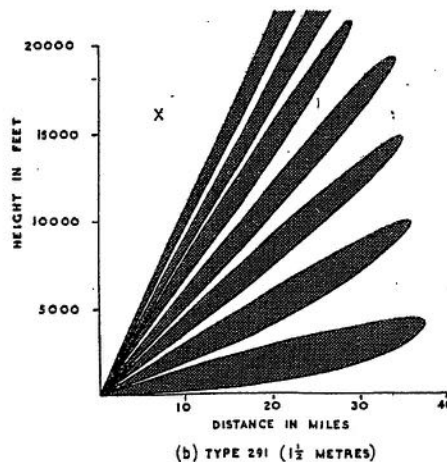
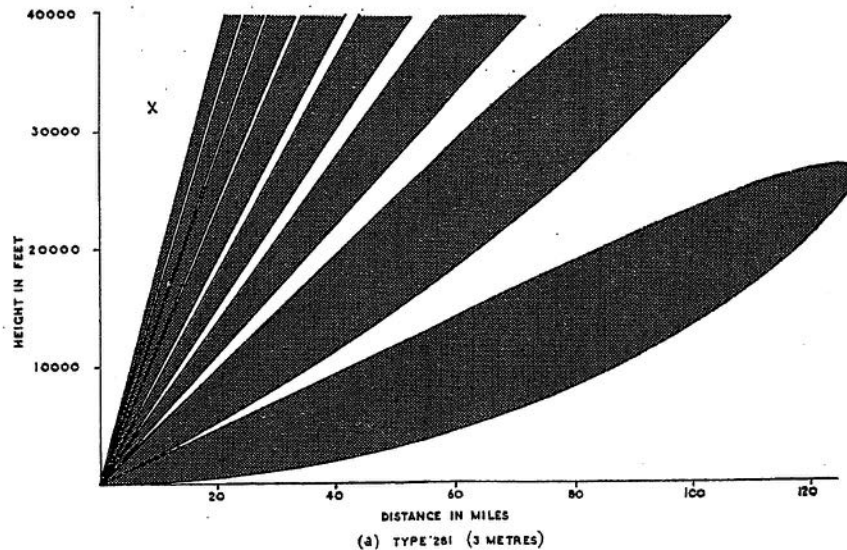


Fig. 8—Typical vertical coverage diagrams for metric sets. See also Fig. 7 for WA type 279 (7 1/2 metres). The numerous narrow lobes and gaps in the regions marked X are not shown.

It will be seen from *Figs. 7 and 8* that for a given aerial height the longer the wavelength the broader the lobes and the fewer the gaps. With WC type 291 (1 1/2 metres) the lobes are relatively narrow and the gaps are numerous and consequently an aircraft echo will frequently disappear as the target approaches.

23. As the wavelength is again decreased the gaps at extreme range become even more numerous, but so fortunately do the lobes so that an aircraft target can be tracked fairly continuously. At close range there may be no gaps since the narrow beam may not strike the sea and so may not experience sea reflection. Typical vertical polar diagrams for decimetric and centimetric sets are shown in Fig. 9 (a) and (b).

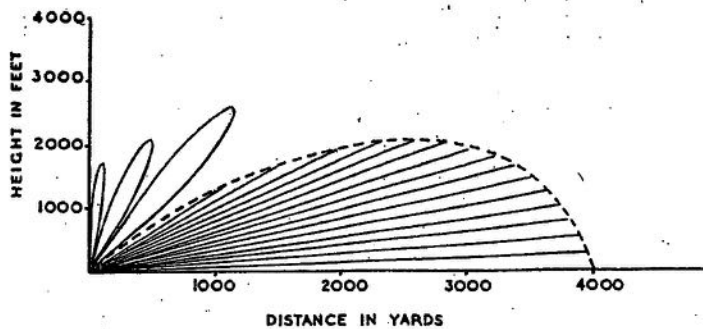


Fig. 9 (a)—Typical Vertical Coverage diagram for decimetric Set (GS type 284) when layed on horizon. Due to sea reflection the "main lobe" is really made up of a large number of narrow lobes, as shown in the inset to Fig. 9 (b) (but in the case of type 284 the lobes are 750 feet apart). This results in rapid fluctuation of the echo as the target approaches.

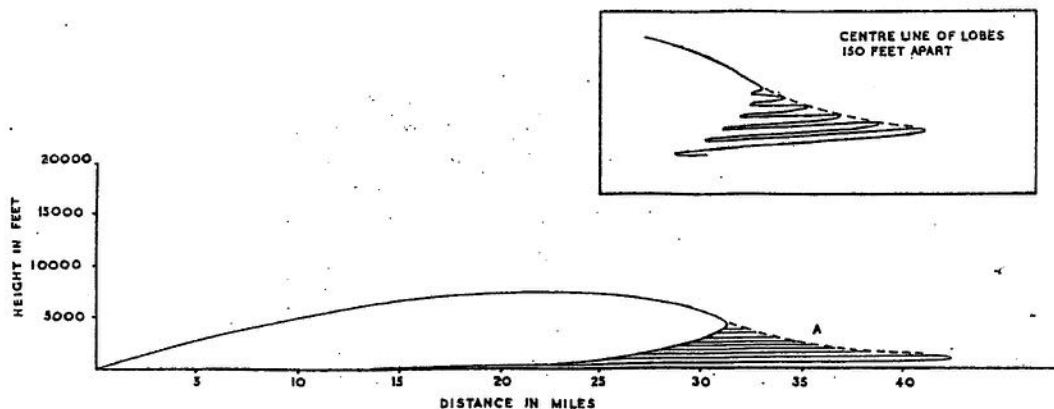


Fig. 9 (b)—Typical Vertical Coverage diagram for Centimetric Set (WS type 277) when layed on horizon. In the region marked "A" sea reflection causes numerous narrow gaps and lobes. This results in rapid fluctuation of the target echo when in this area, of which a portion is shown enlarged in the inset.

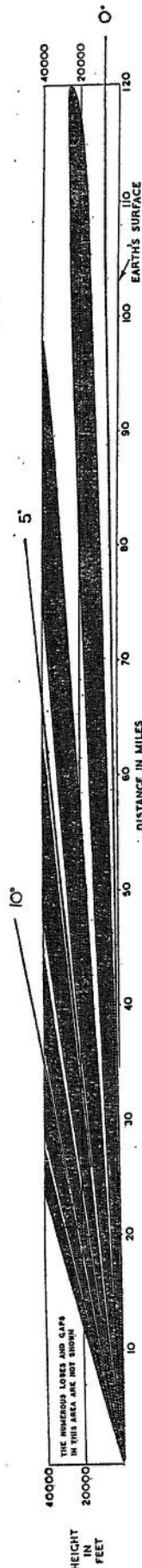


Fig. 11—Vertical Coverage diagram for WA type 281 drawn to true scale. Vertical coverage diagrams are, for convenience, usually drawn with the height scale exaggerated. The above diagram shows the vertical coverage diagram to WA type 281 drawn to true scale, and also the effect of earth's curvature. True angle of sight is also shown. This figure should be compared to the standard method as used in Fig. 8 (a).

24. By tilting up the aerial and using high power, centimetric sets can be made to detect high aircraft at close range, while retaining good surface detection and a narrow beam in the horizontal plane. This property is made use of in the Target Indication Set, WC type 293, whose vertical coverage diagram is shown in Fig. 10.

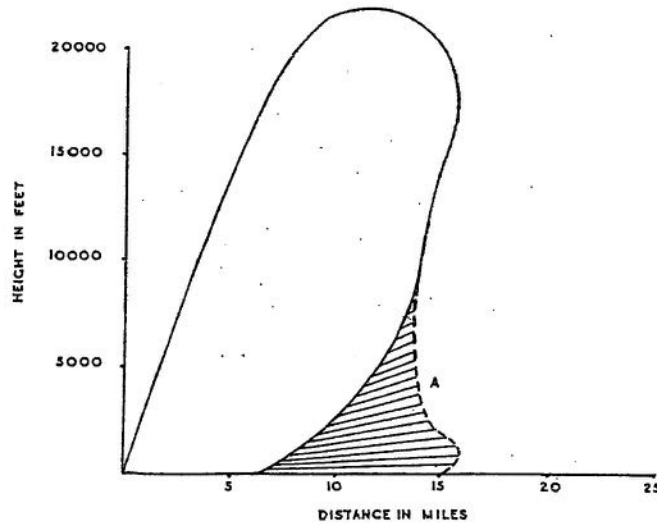


Fig. 10—Vertical Coverage diagrams for Target Indication Set (WC Type 293). In the region marked "A" sea reflections cause numerous gaps and lobes (see inset to Fig. 9 (b)) and the target echo fluctuates rapidly.

25. Alternatively, greater range can be obtained at the expense of high cover at close range. Such a set (WC type 980) is under development for giving plan display for fighter direction. The forecast vertical coverage diagram for type 980 is shown in Chapter XI, Fig. 40.

26.

27. Summing up :—

(a) Metric sets are used for long and medium range air warning.

(b) Decimetric sets are used for gunnery ranging where accurate bearing and maximum range in one direction are required.

(c) Centimetric sets are used for surface warning and low flying aircraft warning, where the energy must be concentrated into the smallest possible beam in order to get maximum range; and also for the latest gunnery ranging sets. They are also used in a different form where short or medium range aircraft cover, combined with precise bearing, is required for target indication or fighter direction.

28. The vertical coverage diagrams shown in Figs. 7 to 9 are of course only typical. The exact pattern will vary according to the type of set and the height at which it is fitted.

29. Before concluding the remarks on vertical coverage diagrams it should be pointed out that, for convenience, they are nearly always shown on a distorted scale, i.e. with the height scale exaggerated. Also, the effect of curvature of the earth is usually omitted. The true appearance is shown in Fig. 11, which is the vertical coverage diagram for WA type 281. This should be compared to the standard method of drawing it (Fig. 8 (a)).

BEARING, BEARING ACCURACY, AND BEARING DISCRIMINATION

30. There are two ways employed in warning radar sets for obtaining the bearing :—

(a) The aerial is trained round by hand right and left of the target. The bearing is read off when the echo is considered to be a maximum on "A" display, *i.e.* when the target is in the centre of the beam. Alternatively, the bearing can be obtained by taking the mean of the two positions where the echo is equally small, *i.e.* as the target leaves the edges of the beam. In WA type 79 there is a special angle-dividing device for doing this expeditiously.

Or (b) the aerial is trained round continuously (usually by automatic means) and the echo displayed on a Plan Position Indicator (P.P.I.) which is explained in *para. 54* below. The echo is then bisected by eye or by cursor and the bearing read off. All modern warning sets will have continuous rotation, because this best suits the P.P.I. which is the most useful form of display for warning purposes.

31. Whichever method is employed it is clear that the narrower the beam (*i.e.* horizontal coverage diagram) the more accurately can the bearing be measured, since there will be a sharper rise and fall of the echo on "A" display as the aerial is trained, or a smaller echo to bisect on the P.P.I.

32. Also it is obvious that the narrower the beam, the easier will it be to distinguish between the two targets at the same or nearly the same range. This is called **bearing discrimination** and good bearing discrimination, while always desirable, is particularly important in gunnery and fighter direction where there are often several targets close together.

33. In gunnery too there is the special requirement to be able to fire at unseen targets, and in order to achieve a bearing accuracy in blind fire which approaches that of visual it is necessary to use a special system known as **beam-switching** (*Fig. 12*).

This consists of splitting the beam into two slightly separated halves, and switching the transmitter and receiver rapidly from one half to the other. Remembering that each beam is "strongest" in the middle, it will be seen that a target at Y will give a much larger echo from the right-hand beam than from the left. The two echoes are displayed side by side (or else superimposed) and it can be seen at once that the target is to the right of the line of sight, and the necessary action can be taken to bring the director on. When a target is at X two echoes of exactly equal height will be seen and the director is then dead on for bearing.

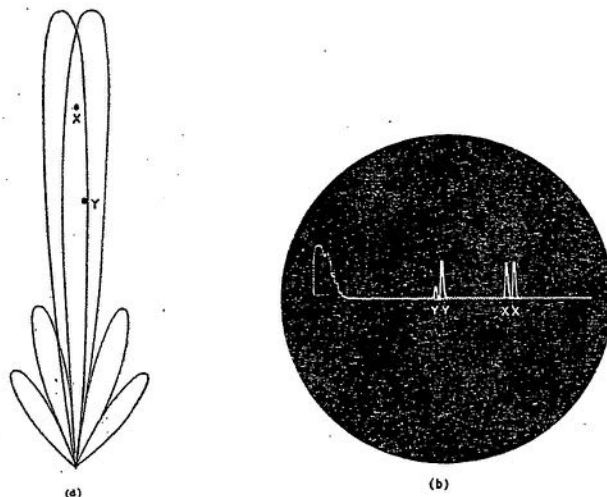


Fig. 12—Fig. 12 (a) is the horizontal coverage diagram for GS type 284 and shows the two slightly separated beams which are energised alternately. (For clarity the side lobes of one beam only are shown). Fig. 12 (b) shows the appearance on the training tube of twin echoes from two targets X and Y. Target X is on bearing and the echoes (X, X) are of equal height. Target Y is off bearing and the echoes (Y, Y) are therefore of unequal height.

RANGE, RANGE DISCRIMINATION AND RANGE ACCURACY

Maximum range

34. It will be clear from what has been said before that the methods of getting the greatest range from radar consist in

(a) Concentrating or focussing the energy into as small a beam as possible.

(b) Using as much power as possible (*see also* "pulse length," *para. 35*).

(c) Mounting the radar aerial as high as possible. Increasing the height of aerial has the effect of depressing the lobes, and so giving better detection of ships, land, low flying aircraft and high aircraft at long ranges; on the other hand if the first lobe of a WA set is depressed too much very high aircraft may be able to "skip" the top of the first lobe and escape detection till they reach the second or even third lobes.

35. Under the best conditions as above, WA sets will detect high aircraft at 120 miles or more. WS sets will detect ships and low aircraft to horizon range (Battleship v. Battleship 25 miles, Battleship v. U-Boat 10 miles, and aircraft at 1,000 feet to 40 miles). Gunnery radar sets will outrange their guns against all but the smallest targets.

Pulse length. Effect on range and range discrimination

36. It will be remembered that the radar transmitter sends out a series of short pulses of radio energy. The **pulse length** or actual duration of each pulse has considerable operational as well as technical significance. On the one hand, a long pulse carries with it more energy than a shorter one, so that a bigger echo is received back (or a greater range can be obtained against a given target). Consequently long pulse lengths are used for warning radar sets, and when there is a choice of pulse length (as there usually is) the longer pulse length should be used when searching.

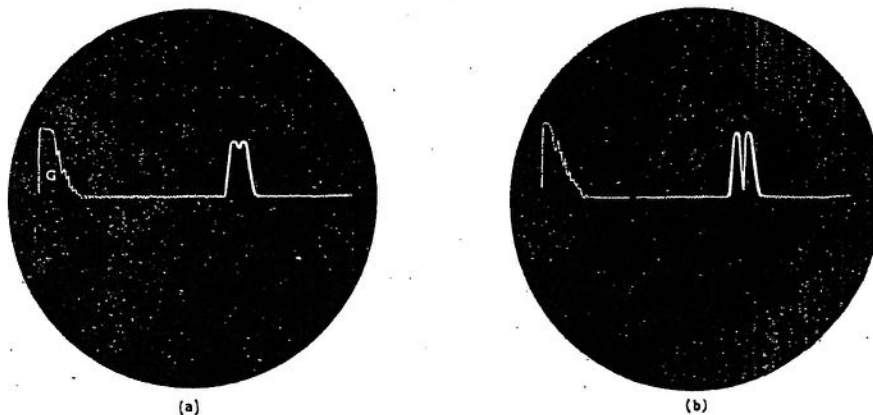


Fig. 13—Effect of using long or short pulse length. Appearance of two echoes at nearly the same range, showing how they tend to merge when using long pulse length (Fig. 13 (a)). Better discrimination on "A" display is obtained by using a shorter pulse length, as in Fig. 13 (b).

37. On the other hand a long pulse length will result in a broad echo, the width on "A" display corresponding to the duration of the pulse. Thus the width of an echo on "A" display using an aircraft warning (WA) set and long pulse length may take up as much as 2 miles on the trace, and this echo will blot out or become confused with the echo from another target near the same bearing and whose range is 2-4 miles greater than the first. This is usually quite acceptable for purely warning purposes but it is obviously not at all acceptable where it is important to distinguish between several targets close together, as may be required in navigation, fighter direction, and gunnery. In order to obtain good **range discrimination** therefore a short pulse length must be used, and the loss in range accepted or compensated for in other ways. In the latest gunnery (GS) set type 274, which has a very short pulse length, the width of a target appears as only 100 yards.

38. Using P.P.I. display, however, range discrimination is not as a rule improved by switching to short pulse length, except on the shortest range scale. This is because the spot of light which paints the echoes has a size which is normally greater than the longest pulse length of the radar set.

39. Whether using "A" display or P.P.I. the use of the shortest range scale will improve range discrimination simply because it spreads out the echoes on the trace and the gaps between them, thus accentuating the targets. Naturally, however, the shortest range scale can only be used if it includes all targets in which the observer is interested.

Ground wave and wave clutter

40. It will be seen from the figures of "A" display so far shown that a large echo always appears at the left or zero end of the scale (marked G in Fig. 13 (a)), and that this echo obscures the first part of the trace. This is called the **ground wave**, and is not really an echo at all but interference caused by the force of the transmitted pulse breaking through direct to the receiver. Using the analogy of sound it corresponds to the local noise made by a man shouting, which may well obscure the echo returning from a nearby cliff. If however the cliff is farther away the man will have stopped shouting by the time the echo has returned, and the echo will be heard.

41. It will be clear from paras. 36 and 37 and Fig. 13 that long or short pulse lengths cause large or small ground waves respectively.

42. Another phenomenon which obscures the early part of the trace is **wave clutter** which is caused by the radar beam striking and being reflected from waves near the ship. With a high power WS set on a rough day it is possible for wave clutter to appear up to several miles.

43. The effects of ground wave and wave clutter can be reduced by making use of "Watson effect" and anti-clutter devices, as described later.

Range accuracy

44. Fundamentally, radar is dead accurate for range provided

(a) the equipment has been properly set up as laid down in the technical handbook of the set.

(b) Any small residual error has been found by methods which are referred to in *Chapter XII* and applied as an Index Correction.

45. Range inaccuracy which is actually experienced in practice is due primarily to human difficulty and error in reading off the scale on the trace, and is thus constant on any range scale. Thus on the long range scale (120 miles) of a WA set an error of $\frac{1}{2}$ -1 mile may be expected. On the medium range scale (75,000 yd.) of a WS set the error should not exceed 200-300 yards. Using shorter range scales the error is proportionately less. On P.P.I. they are about double owing to the shorter length of the trace.

46. These errors are normally acceptable for warning and tactical purposes, but they are not nearly accurate enough for gunnery ranging; and for this purpose special displays are provided either as attachments to or as part of the set. The method used is to select the part of the trace in which the control is particularly interested and expand it electrically, rather like using an electrical magnifying glass. It then becomes possible to read off ranges to an accuracy of 25 yards or even less. Typical expanded traces used for accurate ranging are shown in *Chapter XII*, *Fig. 42*.

RADAR DISPLAYS

47. Radar display is one of the most important radar subjects for the general service officer to understand, because it is now usual to fit displays in the Action Information Centre, far remote from the radar office itself. While the operator will remain the expert in interpreting the display, and will continue to be responsible for watching it and reporting new echoes, an observer in the A.I.C. will miss a lot of useful information if he is unable himself to understand and operate the radar display in which he is interested. Also, he will be unable to work hand in hand with the operator.

48. There are a good many types of radar display, but the only ones in general use are:—

- (a) "A" display.
- (b) Sector displays.
- (c) P.P.I. (Plan Position Indicator).
- (d) Skiatron.
- (e) H.P.I. (Height Position Indicator)—described in *Chapter XI*.
- (f) Expanded traces used for gunnery, described in *Chapter XII*.

"A" Display

49. The idea of an "A" display is already familiar—it shows the range of an echo when the radar aerial is trained in the direction of the target. *Fig. 14* shows an "A" display including an echo, the ground wave, and wave clutter, all of which have already been described.



Fig. 14—“A” Display showing several types of echoes. A—ground wave, B—wave clutter, C—noise or “Grass,” D—a large echo, E—a very small echo appearing as a break in the trace, F—land echoes (numerous jagged peaks).

50. On "A" display aircraft give echoes which pulsate fairly rapidly, and whose mean height varies from a maximum to zero as the target passes through lobes and gaps in the vertical coverage diagram; by comparison ships give steady echoes whose height grows gradually as the range is closed. Land appears as a series of jagged peaks, as shown in *Fig. 14*. Rain clouds may also be detected and appear like land, but are less distinctive and the position of the peaks continually alters.

GROUP II.



PHOTOGRAPH 20—General P.P.I. view showing Isle of Man and shipping, taken with WS type 277 on 0-75,000 yard scale :—

- 1.—Land.
- 2.—Ships and Aircraft.
- 3.—Ground wave and wave clutter.
- 4.—True bearing scale.
- 5.—Ship's head on Relative bearing scale.

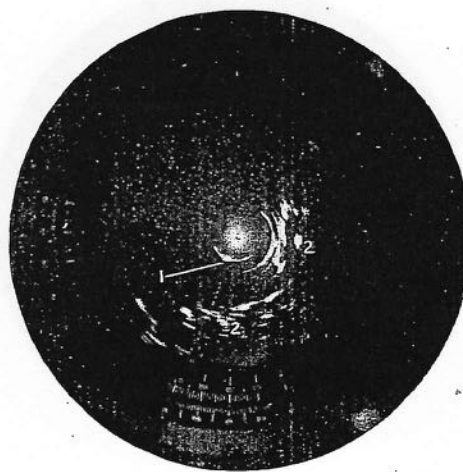


PHOTOGRAPH 21—View of P.P.I. display off Scapa showing battleships and destroyers taken with WC type 293, using 0-15,000 yard scale and input turned down in order to improve discrimination.

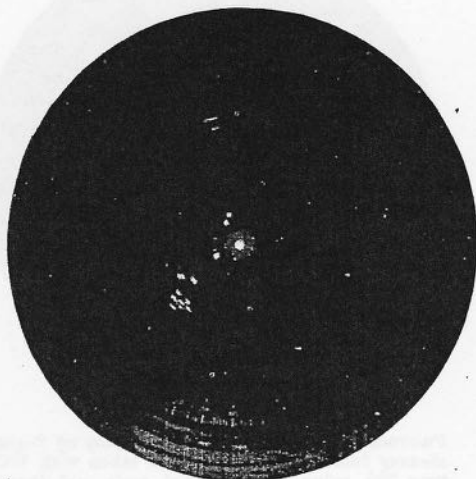
- 1.—Battleship.
- 2, 2.—Side echoes from 1.
- 3, 4.—Destroyer escort.
- 5.—Destroyer.
- 6.—Battleship.
- 7.—Ground wave and wave clutter.



PHOTOGRAPH 22—The same view as in photograph 21, but with the input turned up to its normal "warning" setting. Side echoes from the further battleships have increased, while her destroyer escort is now also showing side echoes. Wave clutter has now obscured the nearer battleship and destroyer.



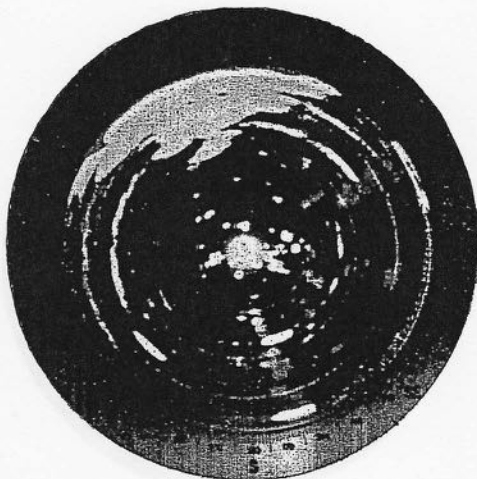
PHOTOGRAPH 23—The same view as in photograph 22, but using the 0-75,000 yard scale. The battleship and her escort (1) appear much nearer the centre of the tube, while land (2, 2) is now shown together with numerous side echoes. The distinctly speckled background indicates that the input is correctly adjusted for best warning.



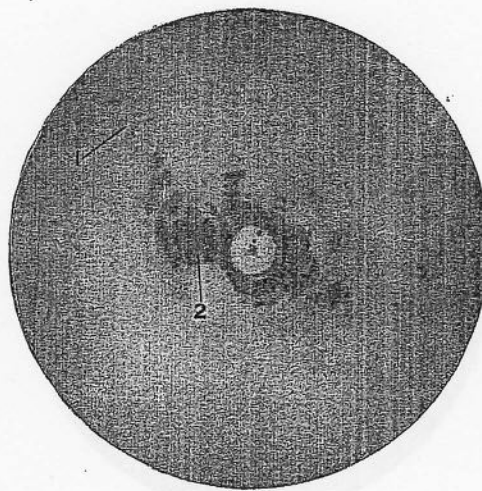
PHOTOGRAPH 24—View of P.P.I. showing an East Coast Convoy, taken with WC type 293 using 0-15,000 yard scale with input turned down to improve discrimination.



PHOTOGRAPH 25—The same as photograph 24, but taken 5 minutes later and with the input returned to its normal "warning" position. The more distant ships (1), barely visible in photograph 24, are now easily seen. The relative position of the Convoy (2) has changed slightly, and many side echoes are now being shown.



PHOTOGRAPH 26—Showing P.P.I. display with the limiter incorrectly adjusted. Giving too much brilliance and a confused mottled effect.



PHOTOGRAPH 27—Surface of Skiatron display, showing painting of dark echoes on light plotting surface.

1.—Aircraft. 2.—Land.

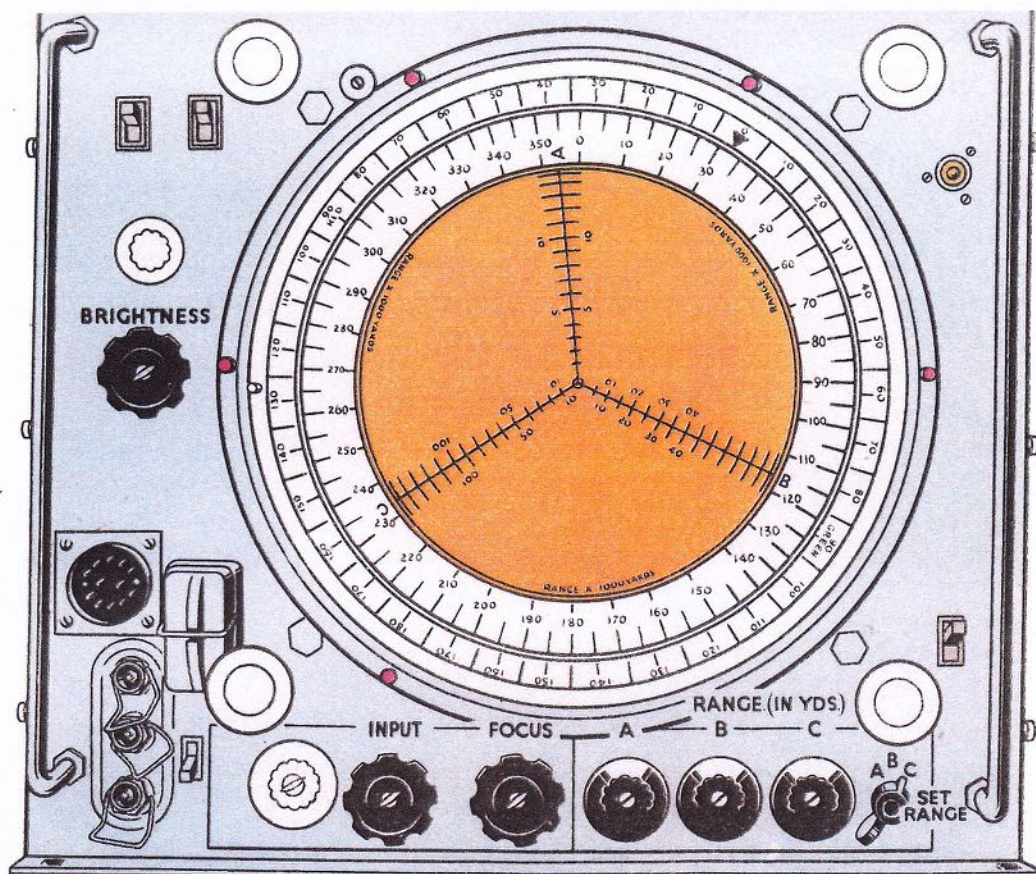


Fig. 15 (a)

STANDARD P.P.I. DISPLAY OUTFIT JE

With rotatable cursor graduated for three range scales. Ship's head shown, at 033°

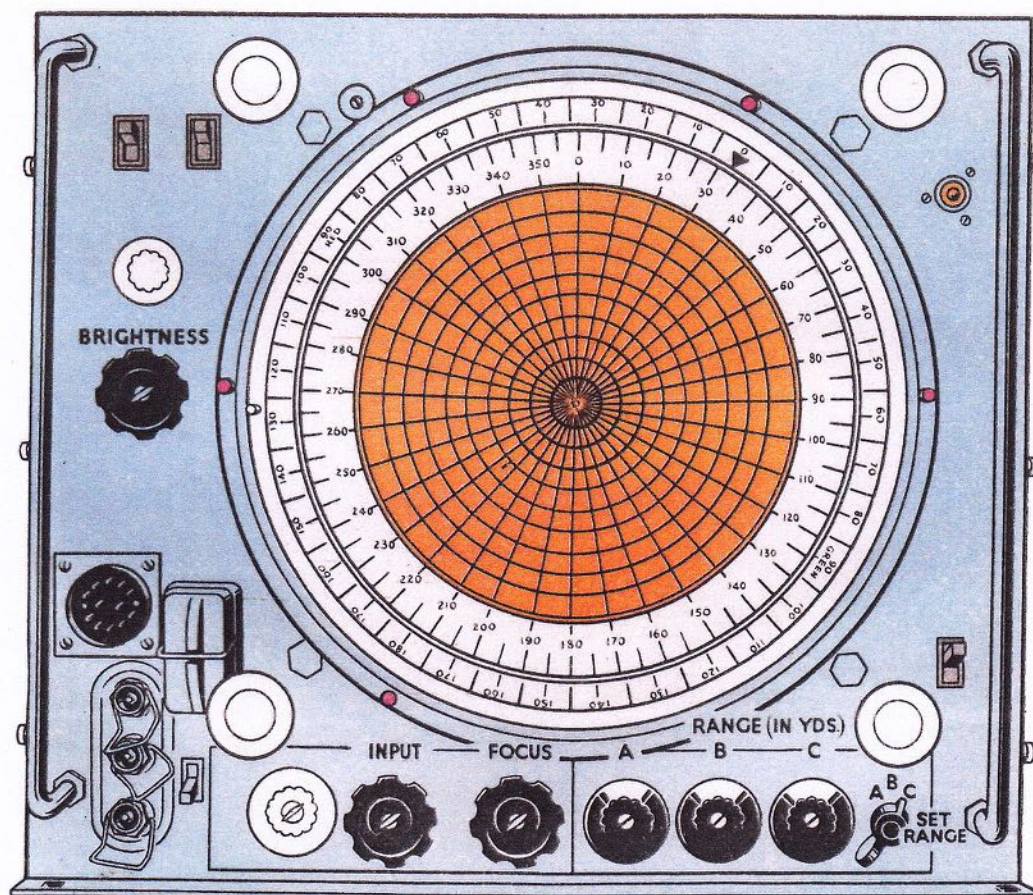


Fig. 15 (b)

STANDARD P.P.I. DISPLAY OUTFIT JE

With fixed perspex mark graduated in 10° bearing lines, and range circles.

51. In *Fig. 14* it will also be seen that the trace instead of being straight and clear has a layer of fuzzy appearance. This is called the **noise** or **grass** and is caused by internal electrical disturbances in the receiver. Its value is that it is one pointer that the receiver is working properly; also it can be used as a guide when adjusting the P.P.I. By turning up the **gain** (*i.e.* amplification) of the receiver, which corresponds to the volume control in a broadcasting receiver, the echo height is increased; so however is the height of the noise, in fact their ratio remains constant. Consequently, on "A" display increasing the gain does not materially help in detecting very weak echoes.

52. "A" displays are not usually found outside the radar office, but must be understood in order to appreciate the working of the P.P.I.

Sector Display

53. A sector display is used in association with a P.P.I. Any desired 6° sector can be selected from the complete plan display and shown separately on a type of "A" display with an after-glow tube. This enables heightfinding and fairly accurate ranging to be carried out without stopping rotation of the radar aerial.

Plan Position Indicator (P.P.I.)

54. On "A" display the position of own ship is on the left, and echoes of targets at which the aerial is pointing are shown along to the right, according to their range; so with one single glance only range can be measured. On P.P.I. both range and bearing are displayed simultaneously. Own ship is in the centre of the face of the tube. As the aerial sweeps round, echoes are traced out (or "painted") not only at the correct range (from the centre of the tube) but also on the correct bearing, leaving a bright arc to mark their position. An after-glow tube is used, so that echoes do not immediately die away, and provided the aerial is kept rotating at a reasonable speed the result is a complete picture or **plan display** of the relative position of all objects within radar range. *Fig. 15* shows the standard naval P.P.I., and *Photograph 20* shows a general view on P.P.I. including land (Isle of Man), ships and aircraft.

55. The top of a P.P.I. is always True North. A relative bearing ring is provided, worked from the gyro, so that the ship's head can be seen at a glance. It would, of course, be operationally handier to have ship's head at the top; but this would mean rotating the whole P.P.I. with the ship's movement, which would be very complicated, or would result in echoes becoming spread out as the ship altered course.

56. *Bearing* is measured by moving one of the lines on the rotatable cursor so that it bisects the echo, and reading off the bearing scale (gyro or relative). A fixed perspex mask may be fitted instead of a cursor; this has radial lines every 10° which can similarly be used to estimate the bearing.

57. For a given sized target the length of the arc of an echo on the P.P.I. corresponds exactly with the width of the horizontal coverage diagram at the range in question. Thus at working ranges and against normal targets P.P.I. echoes from a WA set will be about 40° wide, while those from a WS set will be about 8° wide. Except at close range it is noticeably easier and quicker to get a good bearing off P.P.I. than off "A" display because the eye is better at bisecting an arc than at judging the highest point of a rising and falling echo.

58. At extreme ranges the horizontal coverage diagram is narrower, and the width of the echo on P.P.I. is consequently less; at closer ranges it is wider and at very close range the effect of side lobes is to widen the echo still further.

59. *Bearing discrimination* on P.P.I. can be improved by turning down the "input" (the equivalent of "gain" with "A" display). This has the effect of contracting the horizontal coverage diagram and echoes will therefore be narrower and more easily separated, while side echoes will also be reduced. At the same time, however, the maximum detection range is reduced so that small targets and targets at extreme range may be missed altogether. Consequently the P.P.I. must normally be operated with the Input adjusted for the best warning position, as explained in *para. 68*, and the input should only be turned down while actually separating out targets.

60. *Side echoes.* *Photograph 21* shows a P.P.I. picture taken off Scapa. It will be seen that in spite of the "input" having been turned well down, considerable side echoes are being obtained from the battleship bearing 205° distant about 17,000 yards. It will be observed, however, that they are very easy to identify as side echoes because they are at the same range as the main echo and equally spaced on either side of it. They could not have been identified so quickly on an "A" display. The destroyer escort, being smaller targets, are not showing side echoes at this range. The reason why the second battleship at bearing 260° 5,000 yards is not showing side echoes is that an **anti-clutter device** was fitted. This device cuts out all but very large echoes at close range, and so reduces the effect of wave clutter. It cannot however, cut out the ground wave which appears as a circular area at the centre of the tube.

61. *Photograph 22* shows the same targets, but in this case the input has been returned to its normal (warning) setting. Side echoes are considerably increased, but so is the ability to detect targets. *Photograph 23* is taken from the same position but using a longer range scale; again the input is at its normal setting so that side echoes are obtained from the ships and from the land beyond.

62. *Photographs 24 and 25* show a convoy off the East Coast of England and again illustrate the use of "input" to obtain best discrimination or warning, as required.

63. *Range* is read off by rotating the cursor and reading off from which ever scale is in use. If a fixed perspex mask is fitted instead of a cursor it will have concentric range circles from which the range can be read. These range circles together with the 10° bearing lines make it easier to observe movement of targets than is possible with the rotatable cursor, and also speed up reporting.

64. Either of these methods, however, is rather rough, and to enable more accurate ranges to be taken for tactical or gunnery purposes a sector display may be fitted as described in *paragraph 53*.

65. **ADJUSTING A P.P.I.** It is most important to understand how to adjust a P.P.I. properly since as explained in *para. 47* any officer may have to do it. There are two controls whose use is obvious—see *Fig. 15*.

(a) *Range switch*. The only point worth mentioning is that any range can be selected at a remote position, irrespective of the range used by the operator or by other remote P.P.I.s.

(b) *Focus* which is adjusted to the obviously best position.

66. The other two controls are (c) *Brightness*, and (d) *Input*. These might seem at first to be much the same thing, since they both make the picture bright; but there is a great difference, and the two controls must be operated separately and correctly.

67. The object is, of course, to make echoes stand out as sharply as possible, *i.e.* to get the brightest possible echo and the darkest possible background and so achieve good "contrast." This is easy for strong echoes, but needs careful adjustment if weak echoes are to be seen as well. Turning up the *Brightness* alone lightens both the echo and the background, and one is relatively no better off. On the other hand turning the *Input* up to a certain point increases the echo alone. **The Input is therefore the main control on the P.P.I.**

68. The correct way of adjusting the P.P.I. is as follows:—

(a) Turn the *Input* right down.

(b) Turn the *Brightness* up until the revolving trace is just visible. (This gives all the "Brightness" necessary.) Thereafter LEAVE THE BRIGHTNESS ALONE and clamp it.

(c) Turn up the *Input* until the noise of the receiver shows as a firm speckled background. This shows that the P.P.I. is being "fed" sufficiently.

(d) Adjust the focus as necessary.

69. The P.P.I. is then in the best condition for giving maximum warning, *i.e.* for detecting weak echoes. *Photograph 23* is a good example of a P.P.I. properly adjusted for best warning, and shows the amount of speckled background required.

70. To get better discrimination between several echoes, or cut out side echoes, turn the INPUT down as described in *para. 59*. Remember, however, that maximum warning has been temporarily lost, and do not forget to turn the Input up again.

71. There is a pre-set device inside the P.P.I. called a **Limiter** which controls the maximum brightness of the echoes. This control is set by the radio mechanic, but it is advisable to know if it has been improperly set.

(a) If the Limiter is set too *high*, bright echoes will become blurred and cannot be focussed, and the tube will have an unnecessarily mottled appearance, as shown in *Photograph 26*.

(b) If the Limiter is set too *low* it means that there is not enough signal strength coming from the receiver, and it will be impossible to get sufficient brightness even with the Input turned well up.

(c) When the limiter is set *correctly*, strong echoes will be very slightly out of focus, and all other echoes will be in clear sharp focus.

72. Never turn the Input right up. If this is done it will bring in almost as much noise as signal, and contrast will be lost.

Skiatron

73. The P.P.I. suffers from the drawback that plotting cannot easily be carried out on the tube face, which is in any case rather on the small side. For applications such as Fighter Direction, where immediate and direct plotting of radar targets is important, a modified form of P.P.I. called the "Skiatron" is provided. In the skiatron, echoes from a special Cathode ray tube are projected optically upwards on to an opaque circular ground glass screen and appear as dark echoes (or "stains") on a light background. The ground glass screen is marked with radial bearing lines and concentric range circles, and is used as a plotting surface. *Photograph 27* shows part of a skiatron surface, with echoes.

Lining up a P.P.I. or Skiatron

74. It is necessary to make sure that the electrical trace of a P.P.I. or Skiatron is in fact painting echoes on the same bearing as the radar aerial. To check this a mechanical aerial bearing repeater is sometimes fitted near the display. Alternatively a "ships head light" may be fitted; this flashes each time the radar aerial passes through right ahead and if the trace is out of step an adjustment can be made in the P.P.I. It is, of course, necessary also to ensure that the gyro scale is lined up.

I.F.F. AND INTERROGATORS

90. One of the things that radar cannot do alone is to distinguish between echoes from friendly and enemy ships (or aircraft). To help to overcome this, a radar recognition system is fitted in both ships and aircraft. Each warning radar set has an **interrogator**, which electrically asks the question, "Are you friendly?"; and each friendly ship or aircraft should have an **I.F.F. set (Identification of Friend or Foe)** which, if "interrogated," gives a distinctive "response." If there is no response the target is "unidentified" by radar.

91. The interrogator is a subsidiary radar set working on a metric wavelength (about $1\frac{1}{2}$ metres), and is sometimes fitted so that it rotates with the warning set to which it is an adjunct. In other cases, however, it rotates independently. Owing to space limitations the aerial is small, so that the focus is poor and the beam is wide, giving poor bearing accuracy and discrimination.

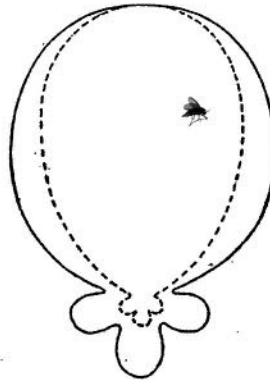


Fig. 16—Horizontal coverage diagram for Interrogator type 243 when triggering I.F.F. or type 253. The outer line is for interrogation of ships and low flying aircraft. The inner (pecked) line is for interrogation of aircraft at long range and is about one-fifth the scale of the outer diagram.

92. Owing to space limitations some interrogators have an all round instead of a directional aerial. The horizontal polar diagram is then of course a circle, and no bearing can be obtained; only range is given. Typical directional and non-directional interrogator aerials are shown in Photographs 1 to 3 and 6.

93. The I.F.F. set or "transponder" consists of two parts:—

(a) A receiver which normally searches over a small wave-band in order to pick up the radar transmission from any interrogator which has been trained on it. When this occurs the receiver actuates:—

(b) a small transmitter which sends back the necessary radar signal (sometimes coded) to indicate friendly character. The returning signal need not be on the same wavelength as the incoming interrogation.

94. Finally the I.F.F. response is picked up by the receiver (or "responder") of the Interrogator and displayed as a distinctive type of echo on the "A" display of the warning radar set, or on a separate "A" display or Sector Display, or in some cases direct on the P.P.I. (or Skiatron). In all cases the range of the I.F.F. response can be allied to the range of the location echo.

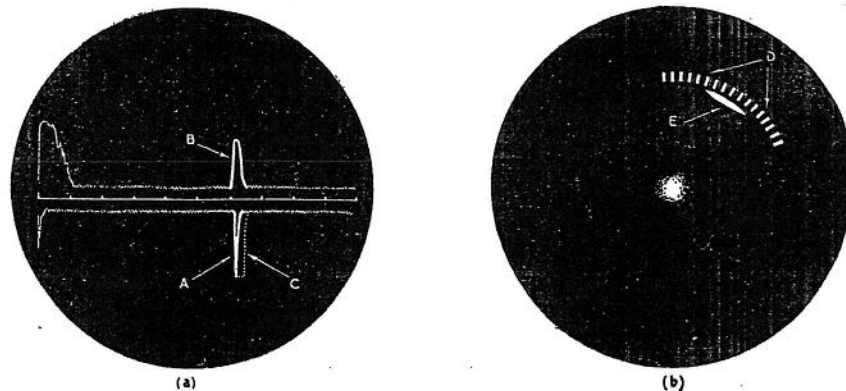


Fig. 17—Appearance of I.F.F. response on "A" display and P.P.I. Fig. 17 (a) shows a normal narrow code I.F.F. response (A) on "A" display. The response appears intermittently on the interrogator trace underneath the associated location echo (B). A wide code response would appear thicker, as shown at (C). Fig. 17 (b) shows the appearance of special "G-Band" I.F.F. response (D) on P.P.I. display, with the associated location echo (E).

95. The I.F.F. set has a non-directional aerial, as shown in *Photograph 1*. This is obviously necessary as the ship or aircraft cannot tell from which direction she may be interrogated and the I.F.F. must therefore keep an all round "watch."

96. The following points should be noted :—

(a) The range of an interrogator is designed to be the same as that of the warning radar set with which it works. The vertical coverage diagram is of the same general shape as WC type 291 (*Fig. 8*), but the ranges are greater and the gaps less pronounced owing to the extreme sensitivity of the I.F.F. transponder.

(b) Provided the Interrogator is strong enough to "trigger" the I.F.F. at all, the strength of the response is constant.

RADAR BEACONS. (Sometimes called **Raçons**.)

97. A radar beacon is really a high-powered I.F.F. set. The difference is one of application. The I.F.F. system is used in conjunction with radar warning sets for recognition, and I.F.F. and location ranges are designed to be as near as possible the same. Radar Beacons, on the other hand, are designed for homing aircraft and so have greater power than I.F.F. in order to give the maximum homing range; also they invariably have a coding device so that the aircraft can be sure he is homing on the right beacon.

98. Otherwise the system is identical with the radar recognition system. The aircraft may be fitted with a special interrogator (called "Lucero") or may use its radar set (A.S.V.) to trigger the Radar Beacon direct.

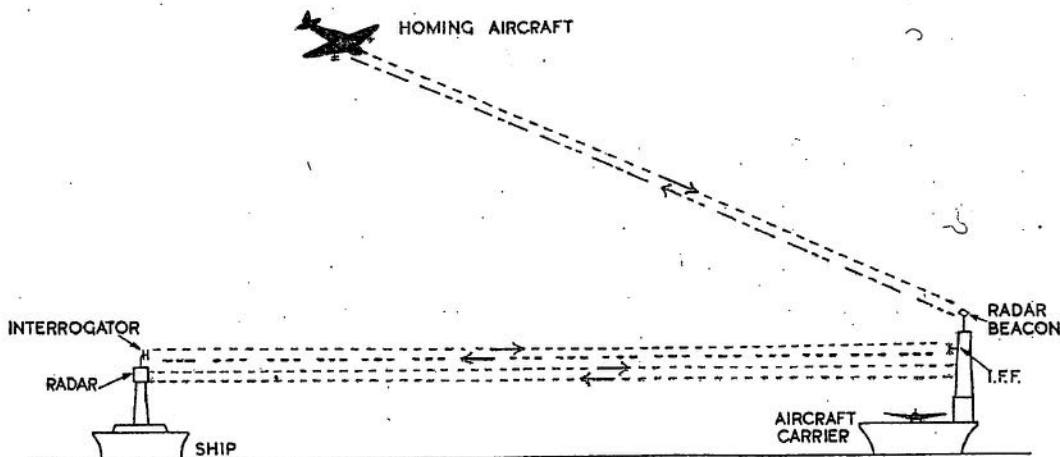


Fig. 18—Simplified diagram showing the operation of Interrogation, I.F.F. response, and use of a Radar Beacon.

- (a) Location radar set obtains echo — — — — (green)
- (b) Interrogator is trained on target and transmits — — — — (red)
- (c) I.F.F. is triggered and gives coded response — — — — (blue)
- (d) Aircraft using A.S.V. locates carrier — — — — and triggers Radar Beacon (red)
- (e) Radar Beacon gives Coded response (UK) — — — — (blue)

99. It should be noted that a radar beacon gives both range and bearing, whereas a W/T beacon gives bearing only.

100. For further details of Interrogators, I.F.F., and Radar Beacons, see *Chapter XIV*.

CHAPTER III

TYPES OF RADAR, AND THEIR CAPABILITIES

HISTORICAL

Radar in Great Britain was first applied ashore to long range warning of aircraft, and the "coastal chain" played a vital part in the Battle of Britain in 1940. Aircraft warning was also the first use to which radar was put at sea: WA type 79 underwent sea trials in 1938 and fitting became general in 1940.

2. GC type 282 made its appearance in 1940 in response to a requirement for protection against the dive bomber. The unexpectedly good ranges obtained led to its adaptation for long range fire control—GS type 284 and GA type 285.

3. For small ships which could not carry a heavy radar set we borrowed and adapted the R.A.F. aircraft "A.S.V." set, which became WC type 286M. Its ultimate successor as a WC set was type 291, but in the meanwhile the urgent requirement to get better ranges against U-boats led to the very rapid production in 1941 of the first centimetric WS set type 271. This set had a considerable influence on the Battle of the Atlantic, and was later modified for bigger ships as types 272/3.

4. Nearly all of the above types now have successors in production or under development, and special sets have been produced for submarines, coastal force craft, and combined operations ships.

5. It is interesting to note that on the whole we have tended to concentrate on anti-aircraft radar (with the notable exception of type 271). By contrast the U.S. have tended to concentrate on anti-ship radar.

DEVELOPMENT AND PRODUCTION

6. It is necessary to realise that radar sets take a long time to develop and produce and get to sea. As an example, the requirements for GS type 274 were laid down early in 1941; the first set went to sea in May 1944. In peace this interval would be a great deal longer, for extensive sea trials would be carried out before going into production. In war it is necessary to take a chance which inevitably means an occasional failure in performance. It is not a coincidence that the only set developed in peace, type 79, is still the most reliable one.

7. The object of stressing this point is to avoid disillusionment. New ideas from sea are very welcome and essential, but they cannot always readily or quickly be converted into a general stock article. Furthermore, there is a severe practical limit to the number of radar projects which can be handled simultaneously; adding another usually has the effect of slowing up the outstanding ones. It is therefore necessary for the Admiralty to decide, from the many projects proposed, which are of most general application and should proceed, and which should not.

CLASSIFICATION OF RADAR SETS

8. Radar sets are classified according to the primary function they are designed to perform, *vide* Table 2. In general, any attempt to make a set perform more than one primary function means that it will do neither really well. A typical example of this is the $1\frac{1}{2}$ metre WC set.

9. **WA (Warning of Aircraft)** sets are designed for long range general warning of high aircraft. They are consequently poor detectors of ships and low aircraft.

10. **WS (Warning of Surface Craft)** sets are designed for maximum range against ships. Consequently they will not detect high aircraft. They will, however, detect low aircraft better than WA sets, which is to be expected from a set with a low concentrated beam.

11. **WC (Warning combined Aircraft and Surface)** sets are of two categories:—

- (a) $1\frac{1}{2}$ metre WC sets (type 291), designed primarily for small ships at a time when only one warning set was carried. Compared to WA and WS sets, aircraft and surface ranges are much reduced.
- (b) 10 cm. WC sets (types 276, 293), designed primarily as Target Indicating sets. Aircraft results are small compared to WA sets, but surface (and low aircraft) results approach those of WS sets.

12. **Gunnery sets (GS, GA, GC and GB)** are designed to form an integral part of their associated fire control equipment.

SITING OF RADAR AERIALS AND OFFICES

13. All warning aerials require an all round view, but this is not possible if more than one type is fitted.

14. WA and WC set aerials usually occupy masthead positions because they are light enough to do so. A low site (*e.g.* type 291 aft in a destroyer) is acceptable as far as range of detection is concerned, but entails a blank arc.

15. WS set aerials cannot usually be mounted at the masthead because of their weight. They must, however, be mounted as high as possible in order to get the best range. Where possible the view, particularly forward, should be unobstructed by stays, aerials or halliards.

16. Gunnery set aerials are mounted on their associated directors.

17. Interrogator aerials are either mounted on top of their parent set's aerial, or fitted separately.

18. Radar Beacons and I.F.F. set aeriels must be mounted high up in order to provide all round coverage.

19. *Figure 71* at the end of the book shows the typical siting of radar aeriels and offices in a cruiser.

20. From an electrical point of view **radar offices** should be sited as near the aerial as practicable in order to keep loss of energy in the feeder to a minimum. On the other hand, it is advisable to site the office in a position where it is reasonably free from gun blast and splinter damage, so that a compromise is usually necessary. Feeders may be open wire, concentric cable, or wave guide, and in each case there is a desirable limit to their length and therefore to the separation between office and aerial. The recommended maximum length of waveguide in the case of types 276/277/293 is 100 ft.

21. Warning sets are at present operated in the receiving (or combined transmitting/receiving) office. The future aim is to site radar offices below armour and to concentrate the display and technical control of each warning set in a **radar display room** remote displays being provided as required in the A.I.C. (*Chapter 6*). The office itself will then contain only a technical watchkeeper, and will be used for actual operating only if the R.D.R. goes out of action.

22. With gunnery sets this principle has already been introduced, and the accurate ranging displays and spotting and training tubes are sited in the appropriate fire control rooms.

TYPES OF RADAR SETS

23. The ensuing paragraphs describe briefly the main types of British and U.S. radar equipment in service in the R.N. *Detailed performance figures are given in Appendix I.* The photographs referred to show the aerial system and site in typical ships, and reference should also be made to *Figs. 19 and 20 in Chapter IV.* In describing a set, one generic name is used to cover all variations, e.g. type 79 is used to refer to the group of sets comprising 79, 79B, 279 and 279B.

WA SETS

(*Note.* Comparisons of the warning and heightfinding capabilities of WA sets are contained in *Chapters 10 and 11.*)

Type 79/79B/279/279B. (*Photographs 1, 2, 36 and 75*)

24. Type 79 is a high power long range aircraft warning set for large ships, operating on 7½ metres, and giving ranges of 50-90 miles against medium and high aircraft. Results against low aircraft and ships are poor.

25. Due to the wide beam, P.P.I. display is not practicable, and bearing discrimination is not good. Bearing accuracy is only about 5-10° for the same reason.

26. Two range scales are provided, 0-24 and 0-120 miles, giving accuracies of ¼ and 1 mile respectively.

27. Type 79 is noted for its reliability and for its consistent results against medium and high aircraft.

28. In type 79 separate receiving and transmitting aeriels are used, and two masthead sites are required. In type 79B a common receiving and transmitting aerial is fitted. In most ships type 79 has been or will be converted to type 79B.

29. In types 279 and 279B an accurate ranging panel was provided. This has now become redundant with the general fitting of gunnery ranging sets.

30. Directional Interrogator type 243M is fitted.

Type 281/281B/281BM. (*Photographs 1-3, 30-33, 35 and 74*)

31. Type 281 is a more powerful long range aircraft warning set for large ships, operating on 3½ metres; and giving ranges of 60-110 miles against medium and high aircraft. These ranges will be increased by 10-15% when a pre-amplifier is fitted. Results against low aircraft are better than with type 79 but do not meet modern requirements. Useful results against large ships can be obtained (Battleship-Battleship 11 miles), and if necessary type 281 can therefore be used as a standby for surface detection.

32. Type 281 is fitted with beam switching giving a bearing accuracy of 1° and good discrimination. Owing to the narrower beam, compared to type 79, P.P.I. and Skiatron display is practicable. When P.P.I. is fitted beam switching is not used and the bearing accuracy is then 3°.

33. On "A" display two warning range scales are provided, 0-30 and 0-100 miles, giving accuracies of ¼ and 1 mile respectively. With the fitting of a pre-amplifier the long range scale is increased to 0-150 miles.

34. On P.P.I. two range scales are provided, 0-50 and 0-100 miles, giving accuracy of better than 2½ miles up to 50 miles. With the fitting of a pre-amplifier the long range scale will be increased.

35. Type 281 gives good results when properly maintained. It is, however, a more difficult set than type 79 to keep up to full efficiency.

36. Type 281B is the one-masted version of type 281. In order to improve P.P.I. display, type 281B will be converted to permit continuous rotation, and will then be known as type 281BM.

37. Type 281 at present has an accurate ranging panel. With the general fitting of gunnery ranging sets this has now become redundant and may be removed in order to provide space for a small aircraft plot or H.F.P.

38. Directional Interrogator type 243 is fitted. With type 281BM two directional interrogators (types 243Q and 941) will be fitted for reasons explained in *Chapter XIV*.

Future R.N. development

39. A new long range warning set type 960 is under development to give longer warning of medium high aircraft. In the first place it will use the type 281BM aerial. Later, larger aeralis will be fitted in ships able to carry them. The set will then be known as type 960M or P, the latter having the largest aeral.

U.S. Type SK (Photograph 37)

40. U.S. Type SK is a long range aircraft warning set, operating on $1\frac{1}{2}$ metres, fitted in certain escort carriers. Ranges of 65-120 miles are obtained against medium and high aircraft, but owing to the larger number of gaps detection is not so consistent as with types 79 and 281. On the other hand low aircraft are detected somewhat better.

41. Bearing accuracy should be 2° . Rotation is continuous and U.S. type P.P.I. is fitted.

U.S. Type SA. (Photograph 45)

42. U.S. Type SA is a medium powered version of type SK, fitted in certain frigates. Ranges of 35-50 miles are obtained against medium and high aircraft. In other respects it is similar to type SK.

43.—45.

WS SETS

46. WS sets are used for surface detection. Modern WS sets are also used for detection of low flying aircraft.

Type 271Q (Photographs 4, 39 and 46)

47. Type 271Q is the present small ship WS set operating on 10 cms., but will be replaced by types 273Q, 277 or 293. In a corvette reliable ranges obtained are 26,000 yds. against a battleship and 8,000 yds. against a U-boat. Low aircraft may be detected up to 10-12 miles.

48. P.P.I. display is fitted and gives bearing accuracy of about 2° except at very close range, when "A" display may have to be used. Aerial stops are fitted, limiting the sweep to 400° . Training is by hand.

49. The aerial system is contained in a lighthouse protected by a perspex lantern. In ships which have not been supplied with all-round perspex lanterns, trouble is experienced from side echoes from the wooden supports.

50. Standard range scales of 0-15,000 yds., 0-75,000 yds. and 0-150,000 yds. are provided for both "A" display and P.P.I. "A" display range accuracy is from 200 to 500 yds. according to the scale in use, and P.P.I. accuracy about half as good. In ships fitted with Squid ranging (*Chapter VIII*) the longest range scale is replaced by one of 0-3,500 yds. giving a range accuracy of 10-15 yds.

Type 273Q/QR (Photographs 30 and 32)

51. Type 273Q is the large ship version of type 271Q, and has full parabolic reflectors as compared to the "cheese" mirrors of the latter set. The larger aerial system, and the greater height at which it is normally fitted, results in considerably greater ranges which approach or equal the optical horizon. In a battleship reliable ranges obtained are 46,000 yds. against a battleship and 15,500 yds. against a U-boat. Low aircraft may be detected up to 12-15 miles. On account of the narrow horizontal beam the aerial is stabilised.

52. Type 273Q is being replaced in large ships by type 277, and is itself replacing type 271Q in certain small ships (*e.g.* Corvettes) which cannot take type 277. In these ships it will prove noticeably better in rough weather on account of the aerial stabilisation.

53. In large ships an accurate ranging panel L18 (accuracy 25 yds.) is added and fitted in the Fire Control Room (type 273QR). See *Chapter XII*.

54. Other details are as for type 271Q.

Type 272P/PR (Photographs 2, 33, 36, 40, 42 and 44)

55. Type 272P is an earlier and lower powered edition of type 271Q, but with the aerial and office separated so that full advantage can be taken of aerial height. It is found in small cruisers, destroyers and sloops. Reliable range from a cruiser is 30,000 yds. against a battleship, and 7,500 yds. against a U-boat.

56. Type 272P is not such an easy set to operate as types 271/3 because the aerial training system is somewhat slow and laborious. For the same reason P.P.I. display is not very satisfactory and is not universally fitted. Type 272P is being replaced by type 293.

57. Two range scales are provided, 0-15,000 and 0-75,000 yds., giving accuracy of 2-300 yds.

58. An accurate ranging panel is added in larger ships (type 272PR). See *Chapter XII*.

Type 277 (Photographs 5, 31 and 34 and Fig. 4)

59. Type 277 is a high power 10 cm. WS set replacing types 271Q and 273Q in frigates and above. Against targets larger than a destroyer, optical horizon range is normal, *i.e.* from a

battleship the range should be 47,000 yds. against a battleship, and 22,000 yds. against a U-boat; and from a frigate 36,000 yds. and 13,000 yds. respectively. When laid on the horizon low aircraft will be detected up to 40 miles at 1,000 feet. These figures may be greatly exceeded under conditions of anomalous propagation.

60. A single exposed parabolic reflector is used and because of the narrow beam it is stabilised. Rotation is normally automatic and continuous (at any desired speed from creeping speed to 15 r.p.m.) In emergency, hand drive can be used.

61. Bearing accuracy on P.P.I. is 1-2°, and better on "A" display.

62. Two pulse lengths are provided, "long" for warning and "short" when better discrimination is required.

63. "A" display and P.P.I. range scales are 0-15,000, 0-75,000 and 0-150,000 yds. Range accuracy on "A" display is from 200 to 500 yds. according to the scale in use, and about half as good on P.P.I. Ranging to the accuracy of the "A" display is possible while sweeping by using the Sector Display L37 and Ranging Outfit RTA (late RTU52). In ships fitted with Squid Ranging (*Chapter XVIII*) the longest range scale is replaced by one of 0-3,500 yds., giving an accuracy on "A" display of 10-15 yds.

64. When fitted in large ships, the aerial can be elevated up to 40° in order to obtain the approximate elevation of targets. Provided the elevation is above 3½° heightfinding is possible to 25 miles with an accuracy of ½-¾° (which represents 1,200-2,500 ft. at 25 miles). When heightfinding it will usually be necessary to put the type 277 on for bearing from the WA set, and while heightfinding all round surface and low aircraft cover will be lost.

Type 276

65. Type 276 uses the same panels as type 277 and differs only in the aerial system which consists of an exposed unstabilised "cheese" reflector. Type 276 was designed as the successor to type 272P, i.e. for ships such as small cruisers where it was desired to make maximum use of aerial height, but topweight precluded the heavy type 277 aerial. To compensate for the lack of stabilisation the vertical beam is 20°, so that low and medium aircraft are detected up to 12-17 miles. Type 276 has been used as an interim target indicating set. Type 276 will, however, be replaced by WC type 293/M in the majority of ships, by changing the aerial because:—

- (a) It has since been found that the majority of small cruisers can take both types 277 and 293.
- (b) In ships such as fleet destroyers which can only take one high-powered set, advantage of the better air cover of type 293 outweighs the slight decrease in surface detection range compared to type 276.

66. Other details are as for WC type 293, *vide para. 100*.

Type 970 (Photograph 49)

67. Type 970 is the R.A.F. airborne blind bombing 10 cm. set adapted for ships and is used for navigation and station keeping in combined operations ships. Range is not very great (M.L. to M.L. 6-8,000 yds.) but a good P.P.I. display is given, which is what is required.

68. The aerial is protected by a perspex lantern and rotates continuously and automatically at 60 r.p.m. P.P.I. bearing accuracy is 2°.

69. P.P.I. range scales are 3½, 7 and 25 miles with accuracy of 50 to 500 yds. according to the scale in use.

70. Type 970 will be converted to a 3 cm. set (type 970M) in order to improve discrimination.

71.-76.

Type 268

77. Type 268 is a lightweight 3 centimetre WS set similar to type 970M and designed for coastal force craft to replace type 291U. Range expected is about 7,000-8,000 yds. against an E-boat or U-boat, and 30,000 yds. against the largest ships. Very low aircraft may be detected at 2-3 miles.

78. The aerial which is similar to that of type 267W (*Photograph 8*) is exposed and rotates continuously and automatically at 22 r.p.m., displaying on P.P.I. with a bearing accuracy of ½°. The P.P.I. is of a special type: by expanding the starting point of the trace and thus pushing out, the echoes from the centre of the tube bearing accuracy can be maintained at close range, but ranging must not be carried out when this device is in operation.

79. P.P.I. range scales are 6,000, 30,000 and 60,000 yds. with accuracy of 50 yds. on the 6,000 yds. scale.

80-84.

Future R.N. Development

85. Optical horizon range having been achieved against all but small targets, no further increase in range of WS sets is likely to be aimed at. Development is likely to take the form of sets with better discrimination and having improved anti-jamming and anti-clutter devices.

86.

U.S. Type SG (Photograph 37)

87. Type SG is the standard U.S. 10 cm. WS set for larger ships. It is fitted in certain R.N. Escort Carriers and frigates. SG1 or SG1a is the modified and improved version. From an escort carrier the range of SG1/a against a large ship is 43,000 yds. and against a U-boat 15,000 yds. Low aircraft may be detected up to 12 miles.

88. Display is on "A" display and U.S. type P.P.I. The exposed aerial rotates continuously and automatically, or can be trained by hand.

U.S. Type SL (Photograph 45)

89. Type SL is the standard U.S. 10 cm. WS set for smaller ships. It is fitted in certain R.N. frigates. From a frigate the range against a large ship is 37,000 yds. and against a U-boat 11,000 yds. Low aircraft may be detected up to 15 miles.

90. The exposed aerial rotates continuously and automatically and displays on U.S. type P.P.I. "A" display and hand training are not provided, with the result that bearing accuracy at close range is poor. For this reason SL has been replaced by SG in many frigates.

U.S. Type SO

91. Type SO, with variations SO1, SO2, etc., is the standard U.S. 10 cm. set for coastal force craft and combined operations ships. It may be met with in certain British vessels. Results are generally similar to type 970. P.P.I. display is provided.

92.-96.

1½ METRE WC SETS**Type 291/291U/291W (Photographs 6, 49-42, 47, 48 and 50)**

97. Type 291 is the standard WC set for small ships and operates on 1½ metres. It is fitted with a different form of aerial in destroyers (291), coastal force craft (291U), and submarines (291W).

98. Owing to the different aerals used and the widely different heights at which they are fitted, results vary considerably and reference should be made to *Appendix I*. In a destroyer useful results are obtained against surface craft (17,000 yds. against battleship, 6,000 yds. against U-boat). Maximum range against aircraft is 30-35 miles, and useful results are very often obtained, but owing to the numerous gaps in the vertical coverage diagram and the comparatively slow sweep rate cover is not completely reliable.

99. The aerial can be trained continuously by hand. "A" display is used with a bearing accuracy of 5°. In destroyers, automatic rotation and P.P.I. will eventually be provided which will improve the reliability of warning.

100. Range scales are 0-15,000, 0-75,000 and 0-150,000 yds. with accuracy of 200-500 yds. according to the scale in use.

101. In ships such as destroyers where a WS set (or type 293) is fitted as well as type 291, the primary function of type 291 is aircraft warning and it may be regarded as a low power WA set. It is, however, a useful standby for surface warning.

CENTIMETRIC WC SETS**Type 293/M (Photographs 7, 31, 34, 35, 41 and 43)**

102. Type 293, which uses the same panels as WS type 277, is a high power 10 cm. WC set and was developed primarily for target indication of aircraft and surface vessels. It is part of the equipment of all ships down to and including fleet destroyers and A.A. sloops.

103. With aerial AUR, aircraft at all heights from 200 ft. to 20,000 ft. should be detected at 15-20,000 yds. With the larger aerial AQR this should be increased to 18-250,000 yds. (type 293M). Surface results vary with the height of aerial; from a battleship the range should be 42,000 yds. against a battleship, and 14,000 yds. against a U-boat.

104. The aerial reflector is an exposed "cheese" tilted up at a slight angle, and rotates continuously (15 or 7½ r.p.m.) displaying on P.P.I. Alternatively hand training and "A" display can be used if it is desired to search a sector. The change from one speed to another, or from automatic to hand, can be made in a few seconds.

105. The object of the high rotation speed (15 r.p.m.) is to ensure getting an up-to-date bearing of fast moving targets at close range, e.g. dive or torpedo bombers. Bearing accuracy from P.P.I. is about ½-1° under favourable conditions, but may be 3-5° if the rate of change of bearing is high. Additional error may be caused if the ship rolls or pitches, due to the lack of aerial stabilisation. A cross-level corrector is being fitted to allow for this.

106. "A" display and P.P.I. range scales are 0-15,000, 0-75,000 and 0-150,000 yds. "A" display accuracy is 200-500 yds. according to the scale in use. In order to attain this accuracy for putting-on gunnery sets or ranging without stopping the sweep, Sector Display panels L37 are fitted in the Target Indication office.

107. In ships where no separate surface warning set is fitted (such as destroyers), or where the WS type 277 is in use for heightfinding, type 293 takes the place of a WS set and therefore has a dual function—tactical and gunnery function.

108. Two pulse lengths are provided, "long" for warning and "short" for use when better discrimination is required. The change can be made instantaneously.

109.

Type 276

110. Type 276, though officially a WS set, has been used as an interim target indicating (WC) set as explained in paragraph 65. By a change of aerial it will in most cases be converted to type 293/M.

Type 267W (Photograph 8)

111. Type 267W is a "hybrid" set for submarines and consists of the addition of a 3 centimetre set to type 291W. There are thus two components:—

(a) The centimetric set for warning of surface vessels and low aircraft.

(b) The $1\frac{1}{2}$ metre set (type 291W aerial and panels) for warning of medium and high aircraft, and as a standby against Surface targets.

112. On account of space restrictions common display and power supplies are used. Consequently only one of the components (a) or (b) can be used at one time, according to the circumstances. Changeover takes about 15 seconds.

113. The centimetric set has a small exposed aerial which normally spins continuously at 8 or 4 r.p.m. and displays on P.P.I. with a bearing accuracy of $\frac{1}{2}^\circ$. Alternatively, hand control and "A" display can be used in order to maintain bearing accuracy at close range. Type 267W will give more accurate data for torpedo control than is possible with type 291W.

114. Preliminary trials, subject to sea experience, show that the centimetric set may give ranges of 10,000 yds. against an E-boat or U-boat, and 30,000 yds. or more against a medium ship. Very low aircraft may be detected at 3-4 miles. For performance of the $1\frac{1}{2}$ metre portion of set, see *Appendix I* under type 291W.

115. "A" display range scales are 7,500, 15,000 and 75,000 yds. with an accuracy of 100 to 250 yds. according to the scale in use. P.P.I. range scales are 15,000 and 75,000 yds.

116. The aerial of the $1\frac{1}{2}$ metre portion of the set has to be lowered to a stowage position before diving (see *photographs 47 and 48* of type 291W.)

117-122.

Future R.N. Development

New Target Indicating Set.

123. Type 992 is being developed to replace type 293. The aim is to increase the rotation speed up to 90 r.p.m. in order to get absolutely up-to-date bearing of close aircraft targets (type 992). This necessitates the development of a new P.P.I. system, since at such a high rotation speed the existing system the aerial and P.P.I. would soon get out of step. Type 992 aerial will be stabilised to prevent bearing error due to roll and pitch.

Fighter Direction Set

124. The fighter direction requirement is to give a continuous plan display of all aircraft out to, say, 70 miles, with good discrimination. Type 980 is being developed on 10 cms. for this purpose, for fitting in aircraft carriers. Type 980 will also be a good surface and low aircraft detector. Heightfinding will not be possible, and for this a separate set (981, SMI or SP) will be used. See *Chapter XI*.

125-126.

HEIGHTFINDING SETS

(See also *Chap. XI*)

127. In order to make use of narrow centimetric beams for direct measurement of the elevation of aircraft, a number of sets have been produced or are under development for use in conjunction with WA and Target Indication sets. To get accurate results particularly in rough weather a high degree of stabilisation in three dimensions is necessary. Heightfinding sets are naturally good surface and low aircraft detectors when layed on the horizon, and can be so employed when not used for heightfinding.

Type 277

128. As described in *paragraph 64*, type 277 can measure approximate elevation. It was not however designed as a heightfinder and the range and accuracy do not attain modern operational requirements, though the results may often be very useful.

U.S. Type SMI (Photograph 35).

129. A number of these sets have been made in the U.S.A. for the R.N. for fitting in Carriers. SMI operates on 10 cms. and has a single parabolic dish reflector. When searching, the aerial sweeps continuously up to 6 r.p.m. and scans a vertical segment of 12° in steps of 3° ; any desired segment can be searched, e.g. $0-12^\circ$ or $8-20^\circ$, up to 75° . Alternatively the sweep can be restricted to any desired horizontal sector, while retaining the vertical scan; or sweeping can be carried out at a fixed elevation.

130. When a target is picked up, either by scanning or by being put on by another radar set, the required elevation and bearing accuracy is achieved by means of a conical scan which

has the same effect as beam-switching in both horizontal and vertical planes. The echoes are matched on meters.

131. Heightfinding is possible up to 50 miles, provided the aircraft is of sufficient height, with an accuracy of 500 feet at 25 miles and 1,000 feet at 50 miles. Aircraft can be followed further, up to 75 miles, but the echoes are too weak for accurate heightfinding.

132. When laid on the horizon optical range should be obtained against ships, and 35-40 miles against low flying aircraft at 1,000 ft.

U.S. Type SP

133. Type SP is an improved version of SM1. It may be fitted in certain R.N. Battleships, Cruisers, and Aircraft Carriers instead of type 277 in order to obtain more accurate heightfinding.

134. Heightfinding is possible up to 60 miles, provided the aircraft is of sufficient height, and aircraft can be followed up to 80 miles. Heightfinding accuracy is slightly less than with type SM1.

135.

Future R.N. Developments

136. Type 981 is being developed as a heightfinder for use in conjunction with type 980 in Aircraft Carriers.

137-141.

GUNNERY SETS—GS.

Type 284 M/P (*Photographs 2, 30, 32, 33*).

142. Type 284M is a 50 cm. GS set for control of main armament in Battleships and Cruisers. Range Battleship-Battleship is 30,000 yds.

143. The aerial and reflector (usually of the "pig-trough" type) are mounted on the main armament director. Capital ships and large Cruisers may have a type 284 aft as well as a GS set (274 or 284) forward.

144. With beam switching bearing accuracy is 5-10 minutes, depending on the rate of change of bearing of the target. Training tubes are fitted in the D.C.T. and T.S.

145. Range Display is on panel L12 in the radar office. Range scales are 0-24,000 and 0-48,000 yds. giving accuracies of 125 and 250 yds. respectively. Arrangements are also made to be able to use the ranging panel L18 (part of type 272/273R) in the T.S. as a standby or in order to get better range accuracy. Range scale of panel L18 is 0-40,000 yds. with accuracy of 25 yds.

146. **Type 284P** has remote display with an accurate ranging panel L24 in the T.S. (range scale 0-40,000 yds. accuracy 25 yds.). Panel L12 is not then fitted in the office, but L18 in the T.S. may still be used as an alternative to L24. A spotting tube is also fitted in the T.S. Otherwise type 284P is similar to type 284M. All 284M sets will be converted to 284P (or replaced by type 274).

147. When type 284P is fitted aft there is not room for the remote displays in the T.S. in addition to those from the forward GS set and they are fitted in the radar office. Arrangements are however made for the after GS set to be switched to the displays in the T.S. when required (e.g. if the forward GS breaks down or will not bear), thus displaying the radar information where it is actually required.

148-149.

Type 274 (*Photograph 9, 31, 34 and 78*)

150. Type 274 is a 10 cm. GS set for control of main armament in Battleships and Cruisers and is replacing type 284 whenever it can be fitted. Range Battleship-Battleship is 42,000 yds.

151. The aerial and "cheese" reflectors are mounted on the main armament director. One type is stabilised, the other not. Capital ships and large Cruisers may have type 274 aft as well as forward.

152. With beam switching bearing accuracy is 5 minutes. A training tube and meter (panel L32) is fitted in the T.S. and a training meter in the D.C.T.

153. Display of range and spotting is on panel L31 in the T.S. Range scale is 0-50,000 yds. with accurate ranging (15 yds.) up to 40,000 yds. The spotting tube displays the portion of the range 1,000 yds. either side of the target.

154. When type 274 is also fitted aft, inter-switchable display arrangements are made as explained in paragraph 147.

155. Splash spotting for range is much better than with type 284 owing to the shorter wavelength and pulse length which give greater range and a range discrimination of 100 yds. It is possible to tell whether shots are left, right, or in line, but quantitative line spotting is not practicable.

156-157.

Future R.N. Development.

158. Future development aims at even better range and bearing discrimination, and a complete plan display of fall of shot round the target so that quantitative spotting for both range and line can be carried out in blind fire (types 930 and 931).

168-172.

179-180

185-188.

Type 262 (Photograph 14)

189. Type 262 is a 3-cm. centrimetric GC set which will eventually replace type 282 whenever it can be fitted. The complete set, including the 2 ft. parabolic mirror which forms the aerial reflector, is fitted on and forms an integral part of the gunmounting or director with which it is associated.

190. Type 262 will be fitted with the following range systems :—

Gunmounting or director	Type
40 mm. Bofors twin S.T.A.A.G. Mk. II mounting ...	262(1)
Close Range Blind Fire Director	262(2)
Close Range System Mk. I Director	262(3)
B.U.S.T.E.R. gunmounting	262(4)

191. The radar beam scans 15° horizontally at the same time elevating 50° in 3° steps. Simultaneously it searches for range about the rough range supplied from the Target Indicating set. "Lookout" bearing and range are provided continuously from the Target Indicating system. When a target is picked up within the space thus searched the aerial "locks on" to the target and automatically provides all the gunnery data required.

192.

GUNNERY SETS—GB**Type 283/M (Photograph 15)**

193. Type 283 is a 50 cm. GB set for control of barrage fire of main armament in cruisers and secondary armament in battleships. The aerial and reflector are mounted on the Barrage Director. In appearance and performance type 283 is similar to type 282, but not of course in function.

194. The auto-barrage unit and Panel L22 are fitted in the radar office. Scale is 0–7,000 yds. with accuracy of 40 yds. Guns are automatically fired from the radar office when the radar echo reaches a pre-selected range, due allowance being made for rate.

195. The training tube is in the Barrage director, and accuracy with beam switching is 30 minutes.

196. **Type 283M** to which type 283 will be modified, has ranging panel L45 with scale 0–12,000 yds. and accuracy 60 yds. Type 283M is used with a Constant Prediction Unit, not an A.B.U., and enables a series of barrages to be fired at the enemy instead of only one as is the case with type 283 and A.B.U.

Type 263

197. Type 263, an adaptation of type 262, will be fitted instead of type 283M, in conjunction with the Medium Range System Mk. I and will give continuous prediction.

198–200.

INTERROGATORS, I.F.F. AND RADAR BEACONS

(See also Chapter 14)

INTERROGATORS**Type 242/M (Photographs 1, 2, 6, 43 and 50)**

201. Type 242 is the Mark III system A-band interrogator fitted in conjunction with WS, WC, and new GA radar sets. There are three types of aerials :—

(a) *Directional and rotatable.* The dipole aerial array either :—

(i) is fitted on top of the parent radar set aerial and rotates with it (types 271, 272, 273, 275)

or (ii) is fitted separately from the parent radar set aerial and rotating in synchronism with it (types 271, 272, 273)

or (iii) fitted separately from the parent radar set aerial and is rotated by hand independently (types 276, 277, 293). This arrangement is necessary because these parent sets are normally rotated continuously at a speed unsuitable for interrogation (as explained in Chapter XIV).

(b) *Non-directional.* In small ships with type 291 a non-directional interrogator aerial of conical type is used, giving range only.

(c) *Directional but fixed.* This type is used in coastal force craft. A form of beam-switching is employed, and interrogation is only possible on ahead bearings.

To get bearing the craft must be swung till the responses are balanced ahead.

202. With Type 242 interrogation range equals or exceeds location range against aircraft. Against ships the reverse is sometimes the case and a more powerful interrogator Type 242M is therefore fitted with high powered 10 cm. sets types 276, 277 and 293.

203. The I.F.F. responses are normally displayed on the "A" display of the parent radar set and appear as intermittent downward "echoes" at a range 200-500 yds. greater than the location echo. When, however, an independently controlled interrogator is fitted a separate sector selector display panel L43 is provided. Bearing accuracy of directional interrogators is 5-10°.

204. Type 242 can also locate targets in the same manner as a radar set. Ranges obtained are about a quarter of type 291.

205.

Type 243/M/Q (Photographs 1-3 and 30-36)

206. Type 243 is the Mark III system A-band directional interrogator fitted with WA type 281. Type 243M is a similar interrogator for WA type 79. The dipole aerial array is fitted on top of the parent radar set aerial and rotates with it (except when types 243Q and 941 are fitted, *see para. 217*).

207. I.F.F. responses are displayed on the "A" display of the WA set and appear as intermittent downward echoes at a range 200-500 yds. greater than the location echo. Interrogation range equals or exceeds location range. Bearing accuracy is 5-10°.

208. *Paragraph 204* also applies to type 243.

Type 244

209. Type 244 is an interrogator, similar to type 242, for use with U.S. type SL. It displays responses on a separate "A" display.

Type 245

210. Type 245 is an interrogator similar to type 243 but separately controlled and with a larger aerial array which gives better bearing discrimination. It is fitted in Fighter Direction Ships.

211-215.

Type 941

216. Type 941 is the G-Band interrogator for type 281BM and will enable responses of friendly fighters fitted with I.F.F. Mark IIIG to be shown direct on P.P.I. or Skiatron display, while type 281 aerial is rotating. (For a full explanation, *see Chapter XIV*). In appearance and characteristics it is similar to type 243.

217. When type 941 is fitted, type 243Q will be fitted instead of type 243 and mounted in a separate position. It will be controlled independently by hand, displaying either on 281 "A" display or on a Sector Selector Display panel L43.

218-223

U.S. Interrogators

224. The following U.S. Interrogators may be met with :—

- (a) **BL** which is a directional "A"-Band Interrogator built into the aerial system of U.S. types SC, SK and SM1.
- (b) **BO** which is a directional "G"-Band Interrogator built into the aerial system of U.S. type SM1.

I.F.F.

Type 253, 253MW, 253P (Photograph 1)

225. Type 253 is the Mark III I.F.F. transponder fitted in ships for ship-ship or aircraft-ship recognition. A conical type of aerial is used.

226. Six different codes and a distress code are provided. In Type 253P morse coding is provided in addition in order to improve security for ship-ship recognition.

227. Type 253MW in Submarines carries out the dual function of an I.F.F. Set and a radar beacon, and can also be used for communicating with aircraft.

228. For fuller particulars and future development *see Chapter XIV*.

229-238.

U.S. Nomenclatures

239. U.S. nomenclatures for I.F.F. sets are as follows :—

- (a) **ABK** = I.F.F. Mk. III.
- (b) **BK** = type 253.
- (c) **SCR695** = I.F.F. Mk. IIIG.

In each case the sets are identical.

RADAR BEACONS

Type 251M, 251P

240. Type 251M is the Standard Radar Beacon in ships for homing aircraft fitted with A.S.V. Mk. II or Lucero. A flat diamond-shaped aerial is used. A multiplicity of morse codes can be set; and are allocated in S.P.2560.

241. In Type 251P the sensitivity is increased to compensate for the low power of Lucero (Interrogator) compared to A.S.V. Mk. II. Ranges obtainable are :—

	<i>Lucero v 251P</i>	<i>A.S.V. Mk. II v 251M</i>	<i>A.S.V. Mk. II v 251P</i>
Aircraft 1,500 ft.	50 miles		60 miles
5,000 ft.	80 miles		100 miles

242-243.

Type 253S

244. The I.F.F. Set type 253 is also used as a shore radar beacon and is then known as type 253S. Range from ships should be about 10-15 miles, but will be influenced by the height of the shore site. Bearing accuracy with type 242 (directional) or type 243 should be 3-5°.

Type 255

245. Type 255 is a marker buoy beacon for use with type 291 in combined operations. The greater power and height of type 291 give better ranges than would be possible with type 242, and bearing can also be obtained. 10 miles is the normal range, with bearing accuracy of 2-5°. Three codes are provided.

Type 256

246. Type 256 is a shore radar beacon for use with type 291 for navigational purposes. The greater power and height of type 291 gives greater range than would be possible with type 242 and bearing can also be obtained. Range should be equal to optical horizon but will be influenced by the height of the shore site. Bearing accuracy is 2-5°. Codes are provided.

247-249.

Type 951

250. Type 951 is a secure marker beacon for use with type 970 in combined operations. It can be used either ashore, or mounted on a buoy, or fitted on board a ship. When fitted in ships, it is used primarily to distinguish important units. Three codes are provided.

251. Type 951 requires to be triggered by type 970 or other 10 cm. set, the responses on 1½ metres being displayed direct on P.P.I. Good P.P.I. display is made possible since a response is only received while the narrow beam of type 970 is actually trained on type 951.

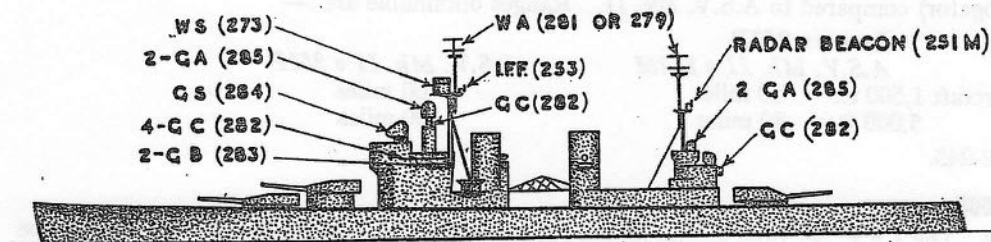
Type 952

252. Type 952 is a secure marker beacon, similar to type 951, under development for use with type 268.

253-259.

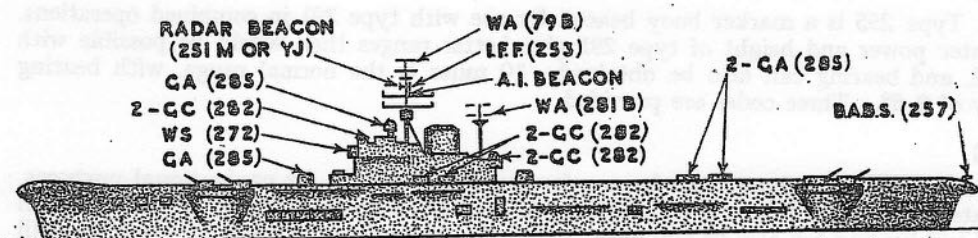
U.S. Type YJ

260. YJ is a radar beacon fitted in certain aircraft carriers for use in homing aircraft fitted with A.S.V. Mark II or Lucero (1½ metres), or ASB (50 cm. A.S.V.). The aerials consist of horizontal U-shaped dipoles for both wavelengths. The beacon can be triggered and will respond on either wavelength.

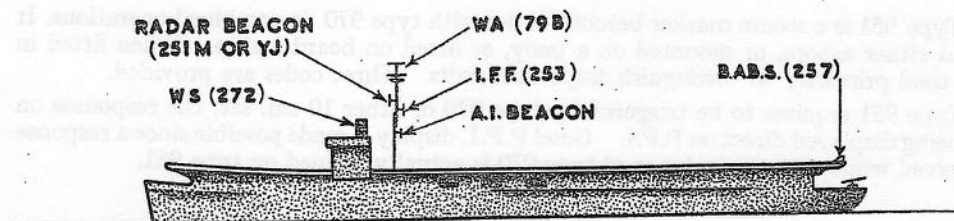


BATTLESHIP

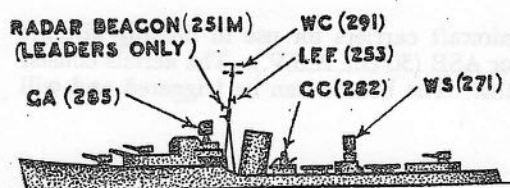
(CRUISER SIMILAR BUT FEWER GUNNERY SETS)



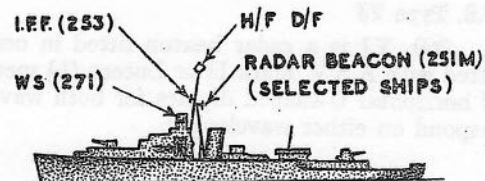
FLEET CARRIER, LIGHT FLEET CARRIER



ESCORT CARRIER

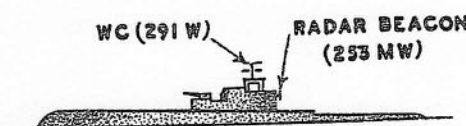


FLEET DESTROYER



FRIGATE

(CORVETTE SIMILAR BUT NO H/F D/F)

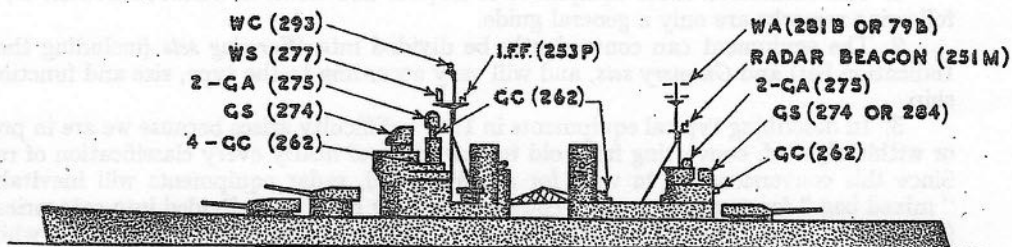


SUBMARINE

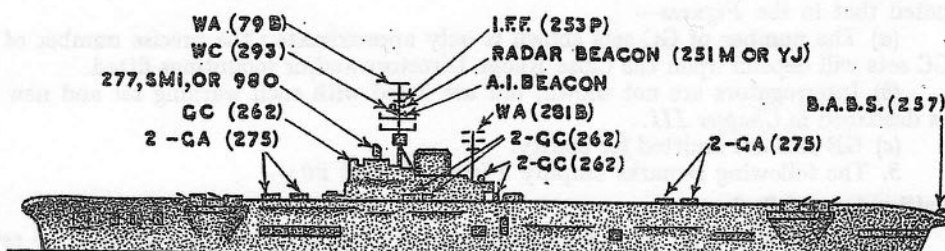


M.T.B., M.C.B.

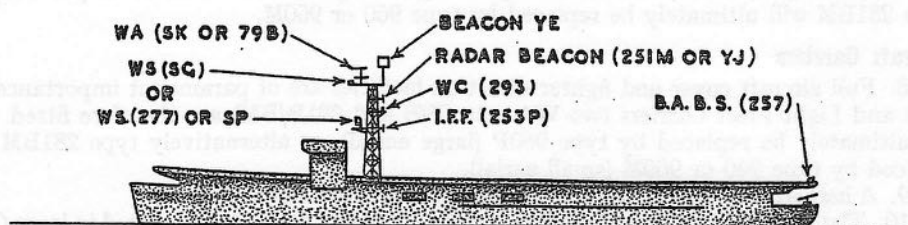
FIG. 19. TYPICAL OLD RADAR EQUIPMENTS.



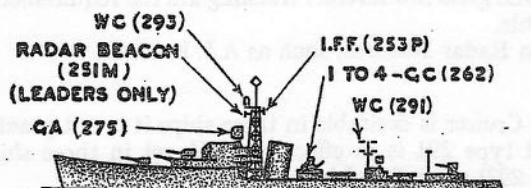
BATTLESHIP
(CRUISER SIMILAR BUT FEWER GUNNERY SETS)



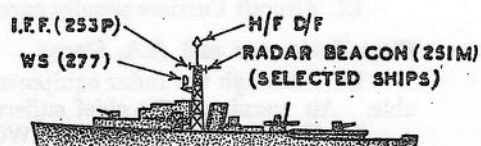
FLEET CARRIER LIGHT FLEET CARRIER



ESCORT CARRIER



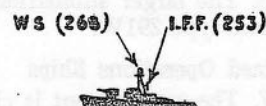
FLEET DESTROYER



FRIGATE
(CORVETTE-WS 273Q AND NO H/F D/F)



SUBMARINE



M.C.B., M.T.B.

NOTE.

WA 960 WILL REPLACE 79B AND 281B

WC 992 WILL REPLACE WC 293

TYPE 981 WILL BE FITTED WITH TYPE 980

FIG. 20. TYPICAL NEW RADAR EQUIPMENTS.

CHAPTER IV

TYPICAL RADAR EQUIPMENTS OF SHIPS

1. The authorised radar equipment of ships is laid down in *CB.3090 Section F*, and the following remarks are only a general guide.

2. The equipment can conveniently be divided into *Warning sets* (including the Target Indication Set) and *Gunnery sets*, and will vary according to the type, size and function of the ship.

3. In describing typical equipments in 1944 a difficulty arises because we are in process of, or within sight of, converting from old to new types of nearly every classification of radar set. Since this conversion has to wait for a refit period, radar equipments will inevitably be a "mixed bag" for some time. For convenience they have been divided into categories "old" (1943) and "new" (1945), but some "new" equipment has already been fitted while much "old" equipment will still be in service in 1945.

4. *Figures 19* and *20* show, diagrammatically, typical "old" and "new" radar equipments, and reference should also be made to the photographs in *Group 3*. It should be noted that in the *Figures*—

(a) The number of GC sets shown is only approximate: the precise number of "new" GC sets will depend upon the Close Range Directors and/or mountings fitted.

(b) Interrogators are not shown, but are fitted with each warning set and new GA sets as described in *Chapter III*.

(c) GB sets are omitted for clarity.

5. The following remarks amplify *Figures 19* and *20*:—

Battleships and Cruisers

6. As will be seen, a large number of gunnery sets are fitted, including 2 GS sets under the new scheme. Small cruisers, however, will have only 1 GS set, and will use the after GA set as a stand-by GS set.

7. WA sets types 281 and 79 are fitted in the proportion 3 : 1 with the object of ensuring that in any large unit there will be both good high and good medium air cover (*see Chapter X*). Type 281BM will ultimately be replaced by type 960 or 960M.

Aircraft Carriers

8. Full aircraft cover and fighter direction facilities are of paramount importance and in Fleet and Light Fleet Carriers two WA sets (79B and 281B/BM) are therefore fitted. These will ultimately be replaced by type 960P (large aerial), or alternatively type 281BM will be replaced by type 960 or 960M (small aerial).

9. A heightfinder (SM1, SP, or later type 981) is fitted where possible.

10. The fighter direction plan display set type 980 will ultimately be fitted in large Carriers.

11. Escort Carriers have a reduced equipment (*e.g.* only 1 WA set) and their equipment varies considerably because some were built in the U.S.A. and some in the U.K. In **Assault Carriers** fighter direction is important and therefore 281B or SK with SP is desirable. In **Convoy Escort Carriers** rough high air cover and good low aircraft tracking are the requirements, and types 79B and 277 are therefore desirable.

12. Aircraft Carriers usually carry extra Radar Beacons, such as A.I. beacons.

Fleet Destroyers and A.A. Sloops

13. Although the radar equipment of a Cruiser is desirable in these ships it is not practicable. Air warning is the chief sufferer, and type 291 is in effect the WA set in these ships.

14. The target indication set (WC type 293) when fitted is also the ships WS set.

Frigates and Corvettes

15. The emphasis is on U-boat detection and the best possible WS set is fitted, *i.e.* types 277, 273Q, SG or in some cases SL. On account of the A/S requirement H/F D/F is normally fitted instead of type 291 in Frigates. Corvettes have neither. GC sets may in future be fitted in frigates.

Submarines

16. The larger submarines will be fitted with type 267W, but smaller submarines can only take type 291W.

Combined Operations Ships

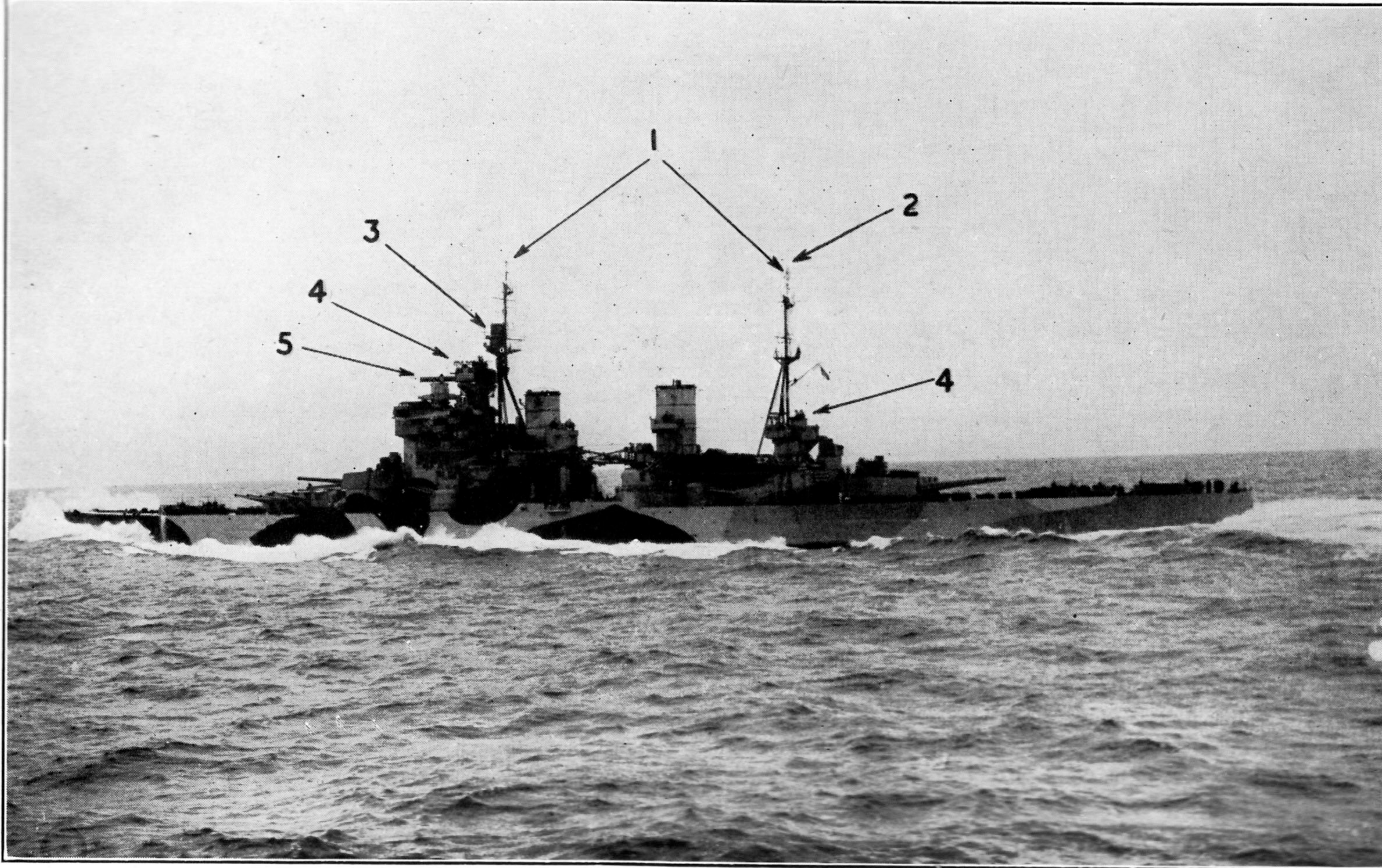
17. The requirement is chiefly navigational, so the best practicable WS set with P.P.I. is desirable. In practice a variety of WS sets including type 970 may be found.

Special Fighter Direction Ships (L.S.F.) and Tenders

18. A small number of ships are fitted for fighter direction duties in combined operations. They carry the maximum practicable number of WA, Fighter Directing, and Heightfinding radar sets. These may be R.N., R.A.F. or U.S., and sets are sometimes duplicated to avoid blank arcs and to guard against breakdown.

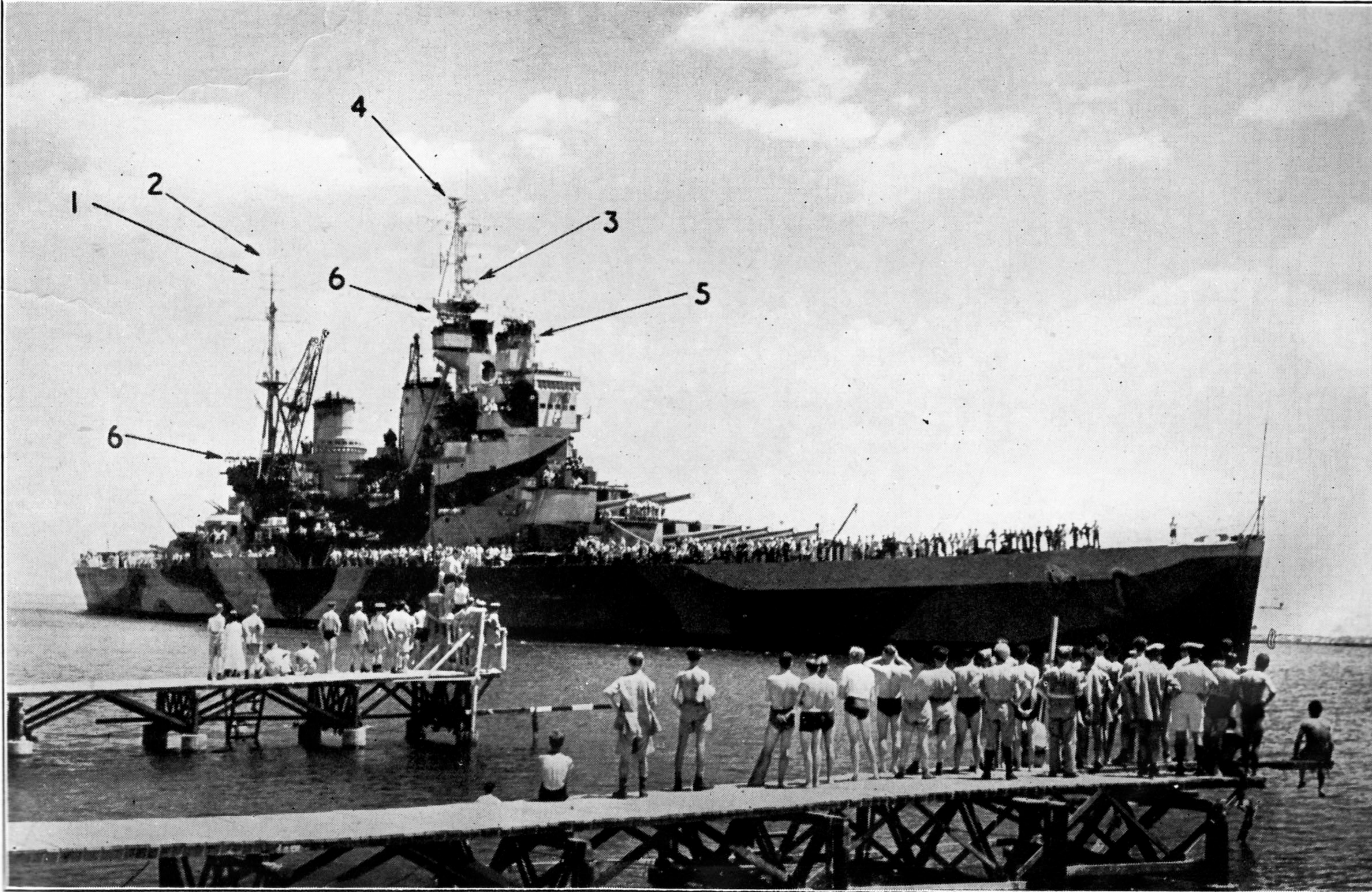
Convoy Fighter Directing Ships

19. These differ from Special Fighter Directing Ships in that they have to keep the sea for longer periods, and this reduces the number of radar sets that can be fitted since greater precautions against weather damage are necessary.



PHOTOGRAPH 30—Battleship ("Howe") with old radar equipment showing:—

- 1.—WA type 281.
- 2.—Interrogator type 243.
- 3.—WS type 273 QR.
- 4, 4.—GA type 285.
- 5.—GS type 284.



PHOTOGRAPH 31—Battleship ("Howe") with modern radar equipment showing :—

1.—WA type 281B.

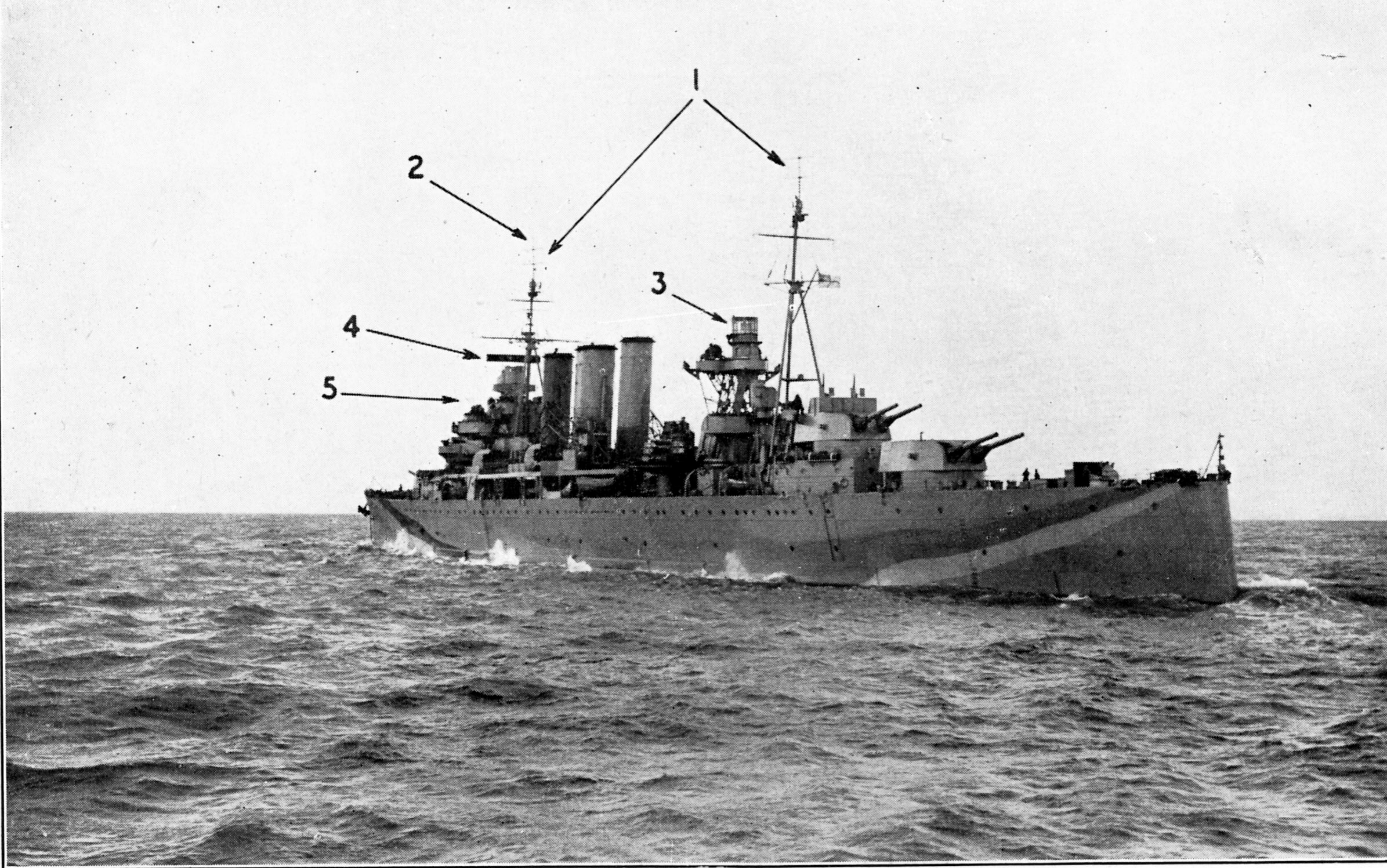
2.—Interrogator type 243.

3.—WS type 277.

4.—WC type 293 (Target Indication set).

5.—GS type 274.

6, 6.—GA type 285.



PHOTOGRAPH 32—8-in. Cruiser (" Kent ") with old radar equipment showing :—

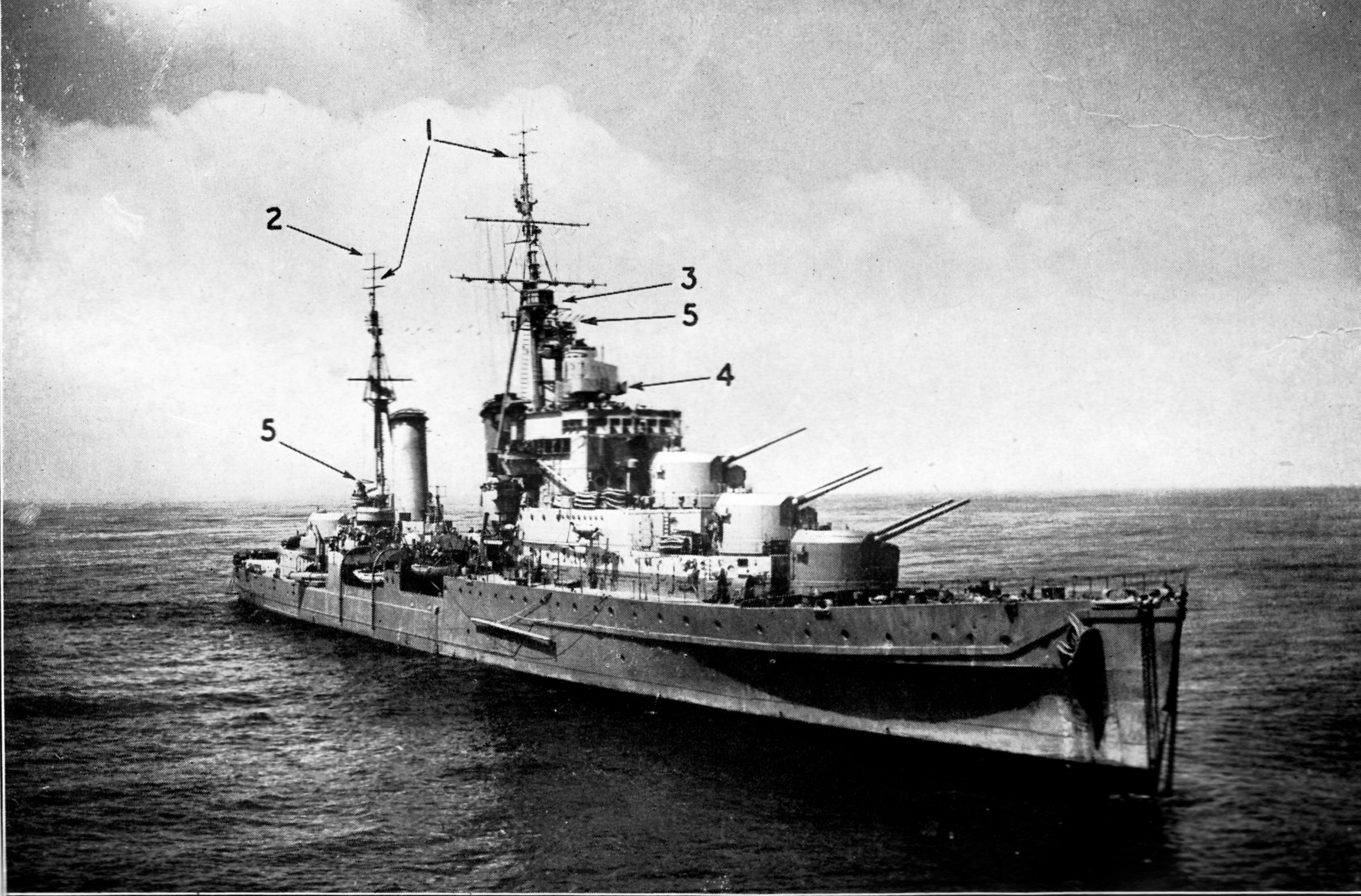
1.—WA type 281.

2.—Interrogator type 243.

3.—WS type 273Q.

4.—GS type 284.

5.—GA type 285.



PHOTOGRAPH 33—5.25-in. Cruiser (" Dido ") with old radar equipment showing :—

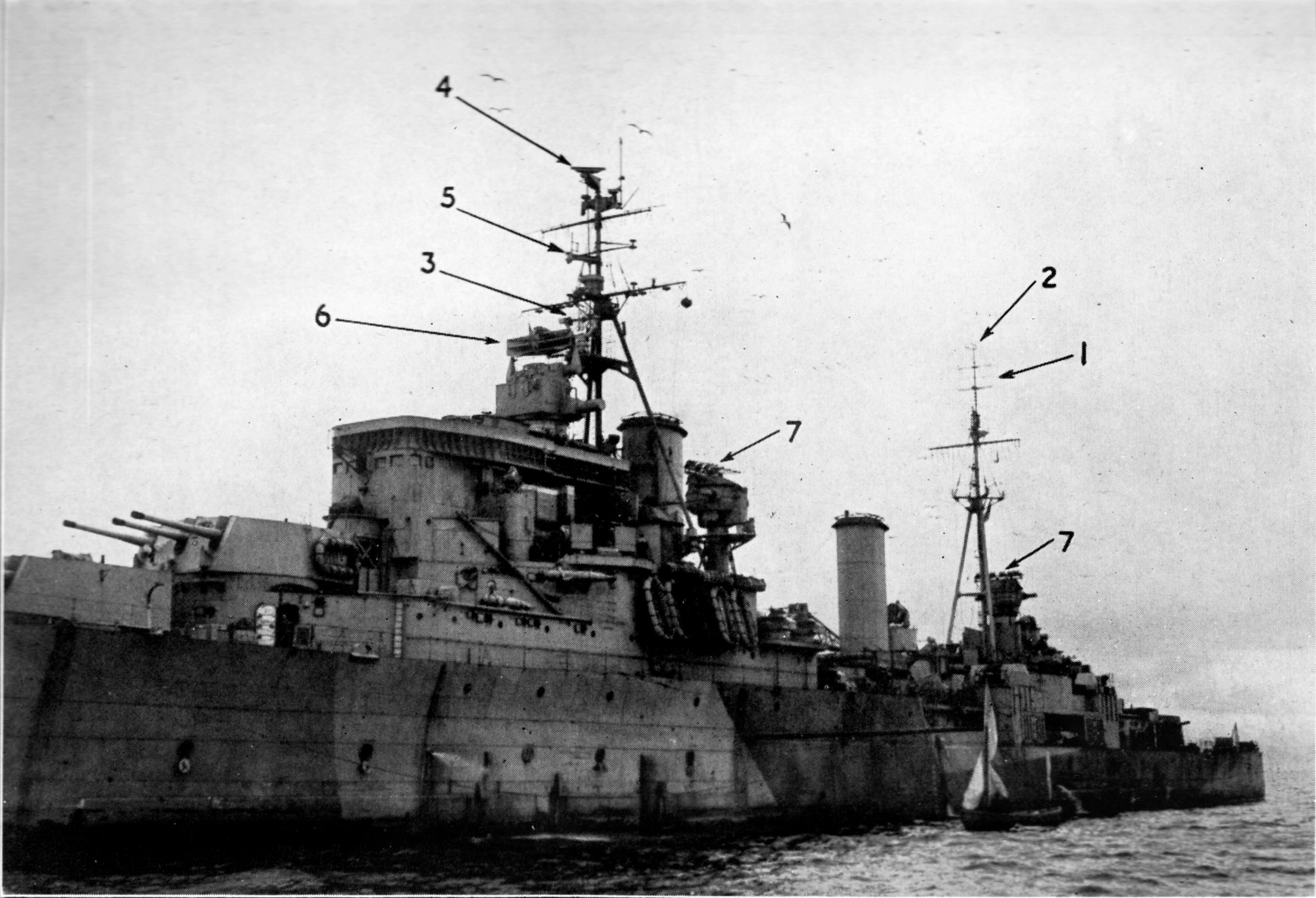
1.—WA type 281.

2.—Interrogator type 243.

5, 5.—GA type 285.

3.—WS type 272P.

4.—GS type 284.



PHOTOGRAPH 34—6-in. Cruiser (“Swiftsure”) with modern radar equipment showing :—

1.—WA type 281B.

2.—Interrogator type 243.

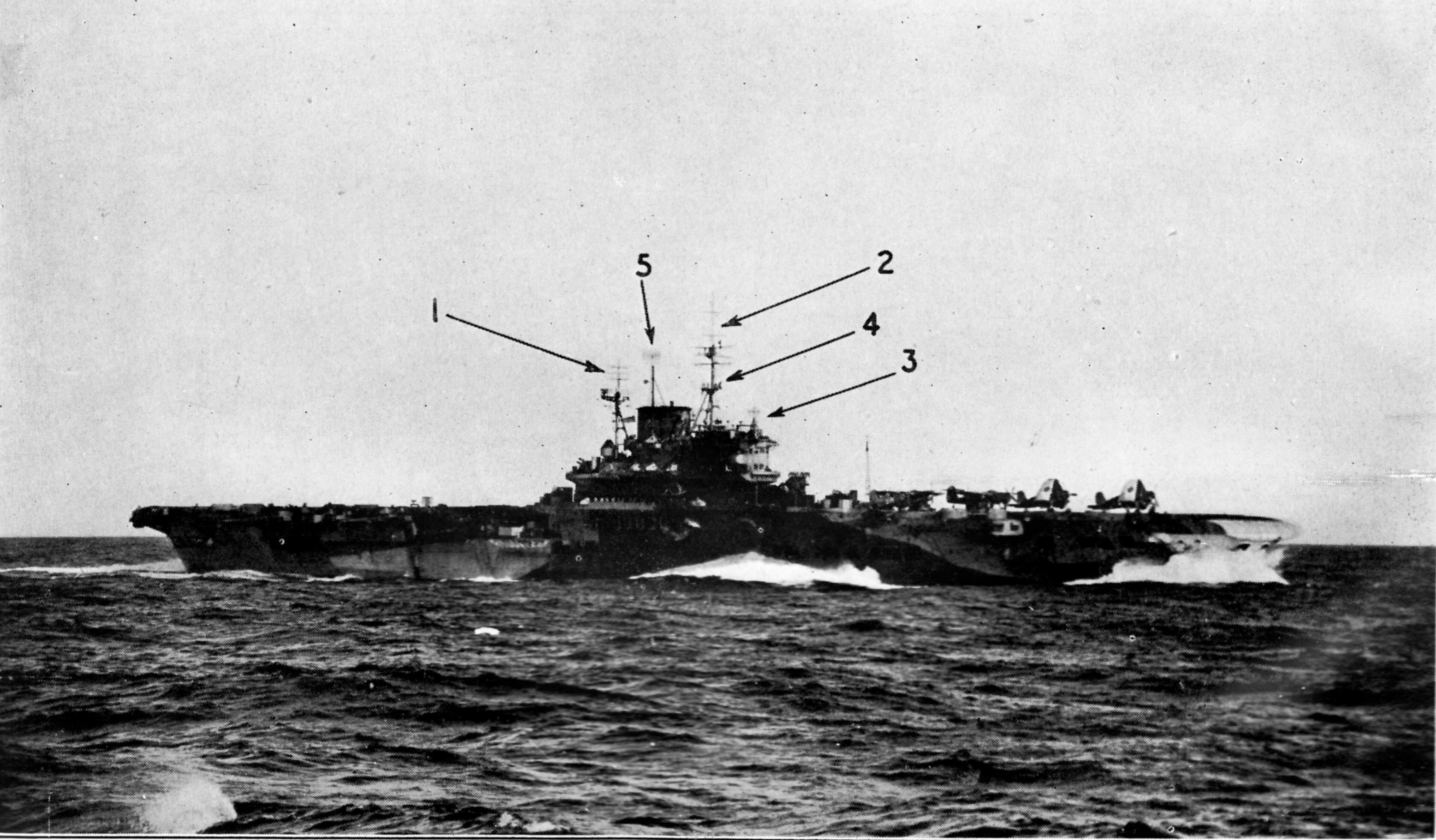
3.—WS type 277.

4.—WC type 293 (Target Indication set).

5.—Interrogator type 242.

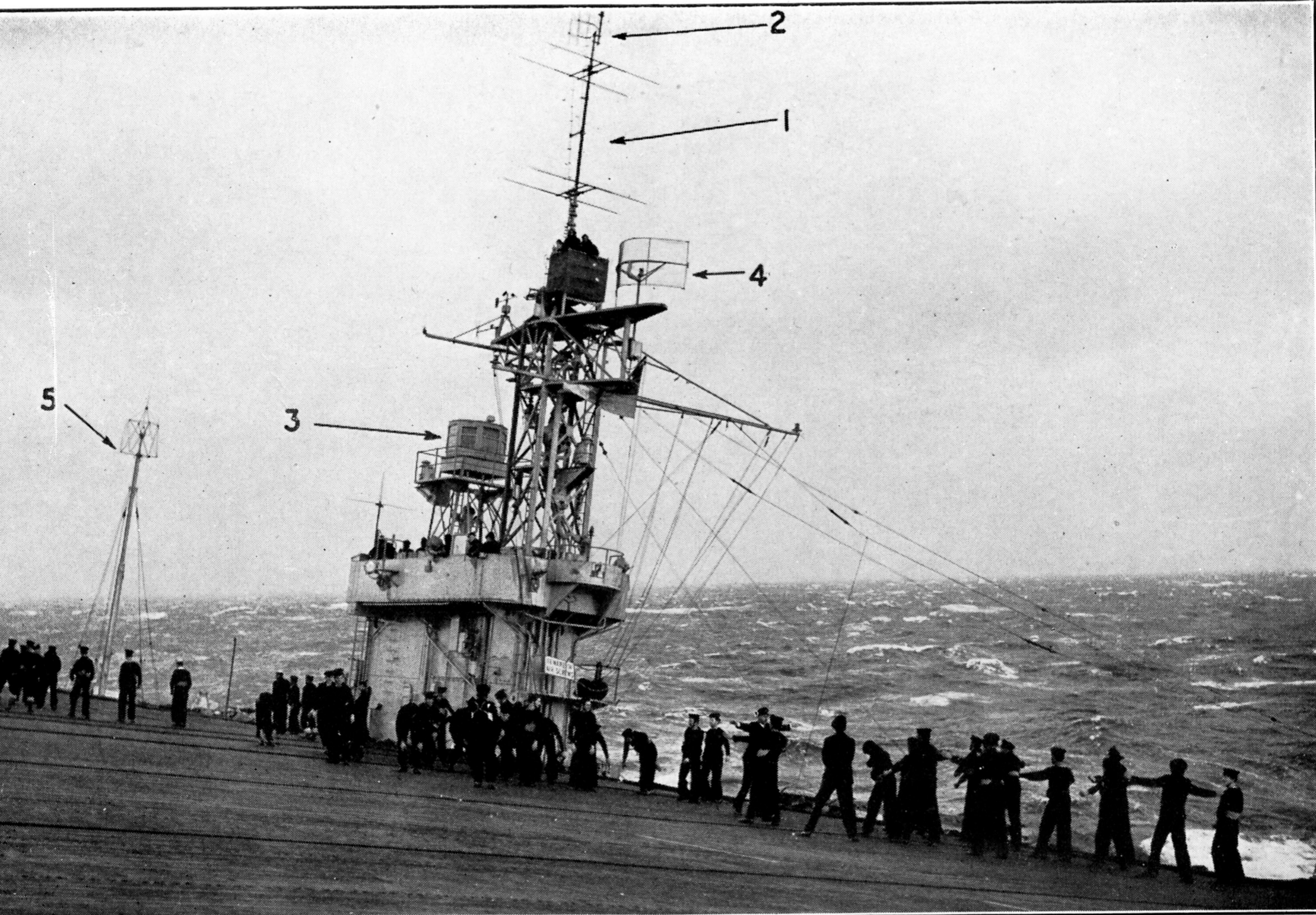
6.—GS type 274.

7, 7.—GA type 285.



PHOTOGRAPH 35—Fleet Carrier ("Victorious") with modern radar equipment showing :—

- 1.—WA type 281B and Interrogator type 243.
- 2.—WA type 79B and Interrogator type 243M.
- 3.—Heightfinding set type SM1.
- 4.—WC type 293 (Target Indication set).
- also 5.—Radio Beacon type YE.



PHOTOGRAPH 36—Escort carrier ("Stalker") with British equipment showing:—

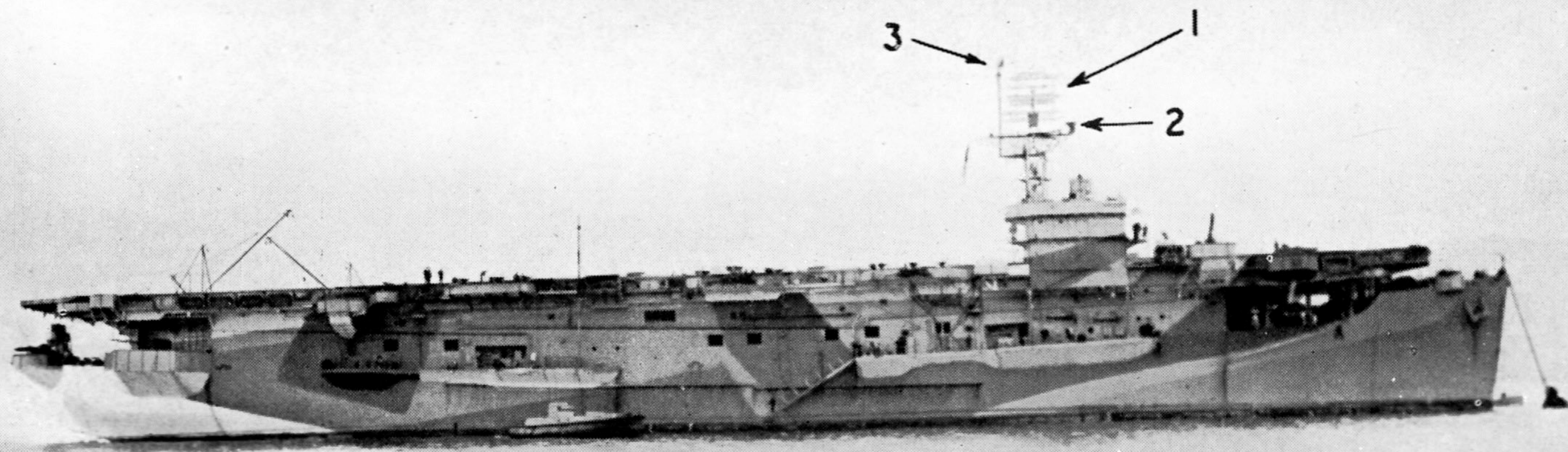
1.—WA type 79B.

2.—Interrogator type 243M.

5.—H/F D/F,

3.—WS type 272 P, also

4.—Radio Beacon type YL.

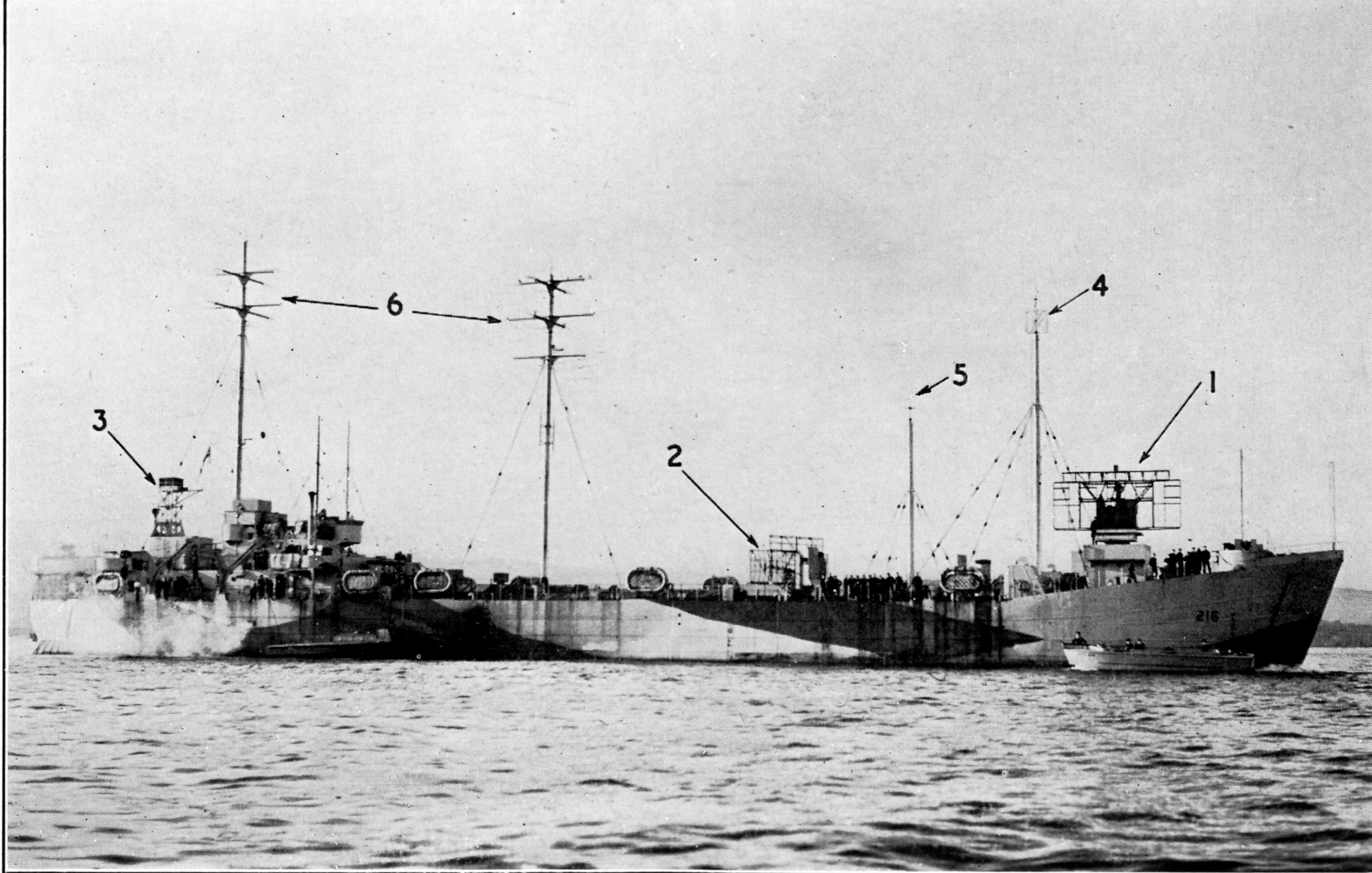


PHOTOGRAPH 37—Escort carrier ("Premier") with U.S. radar equipment showing :—

1.—WA type SK (which includes Interrogator BL).

2.—WS type SG.

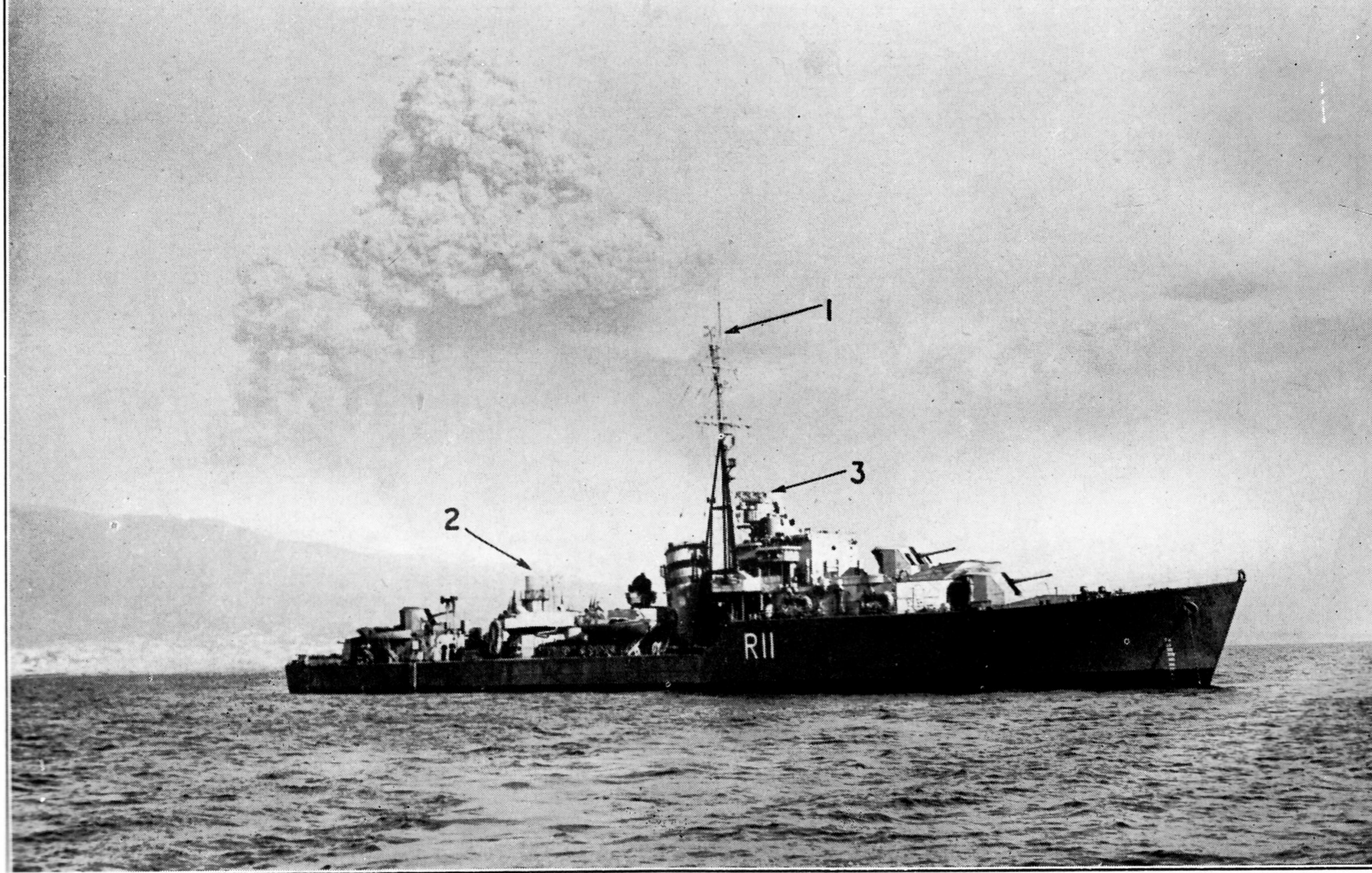
also, 3.—Radio Beacon type YE.



PHOTOGRAPH 38—Fighter Direction Tender with special radar equipment for Assault Operations showing:—

- 1.—1½ metre G.C.I. with built-in interrogators.
- 2.—50 c.m. G.C.I.
- 3.—A.I. Radar Beacon.

- also, 4.—H/F D/F.
- 5.—V.H/F D/F.
- 6.—R/T aerials.



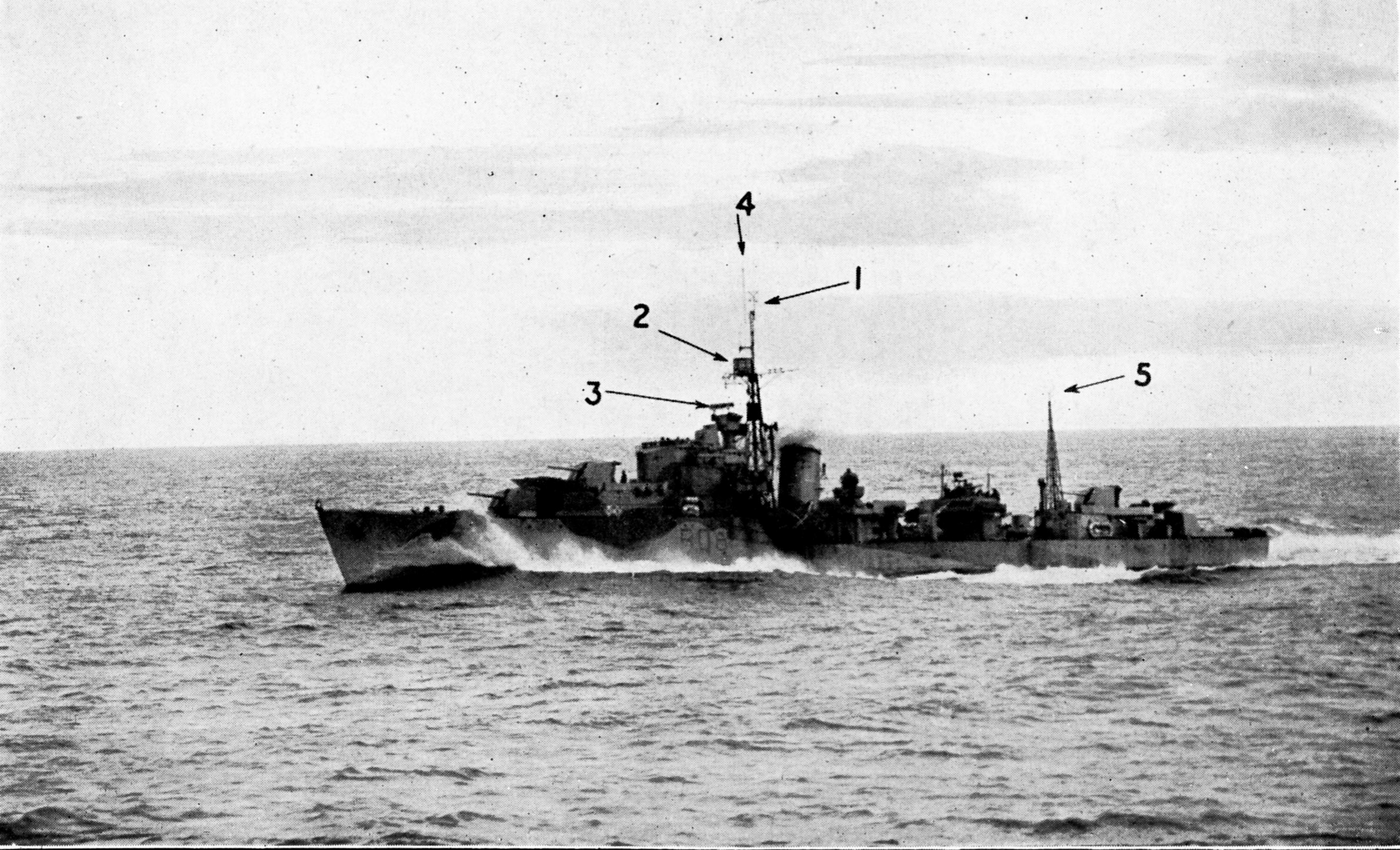
PHOTOGRAPH 39—Fleet destroyer ("Tumult") with old radar equipment showing:—

1.—WC type 291.

2.—WS type 271Q.

3.—GA type 285.

(Mount Etna erupting in the background.)



PHOTOGRAPH 40—Fleet destroyer ("Savage") in intermediate stage of radar equipment showing :—

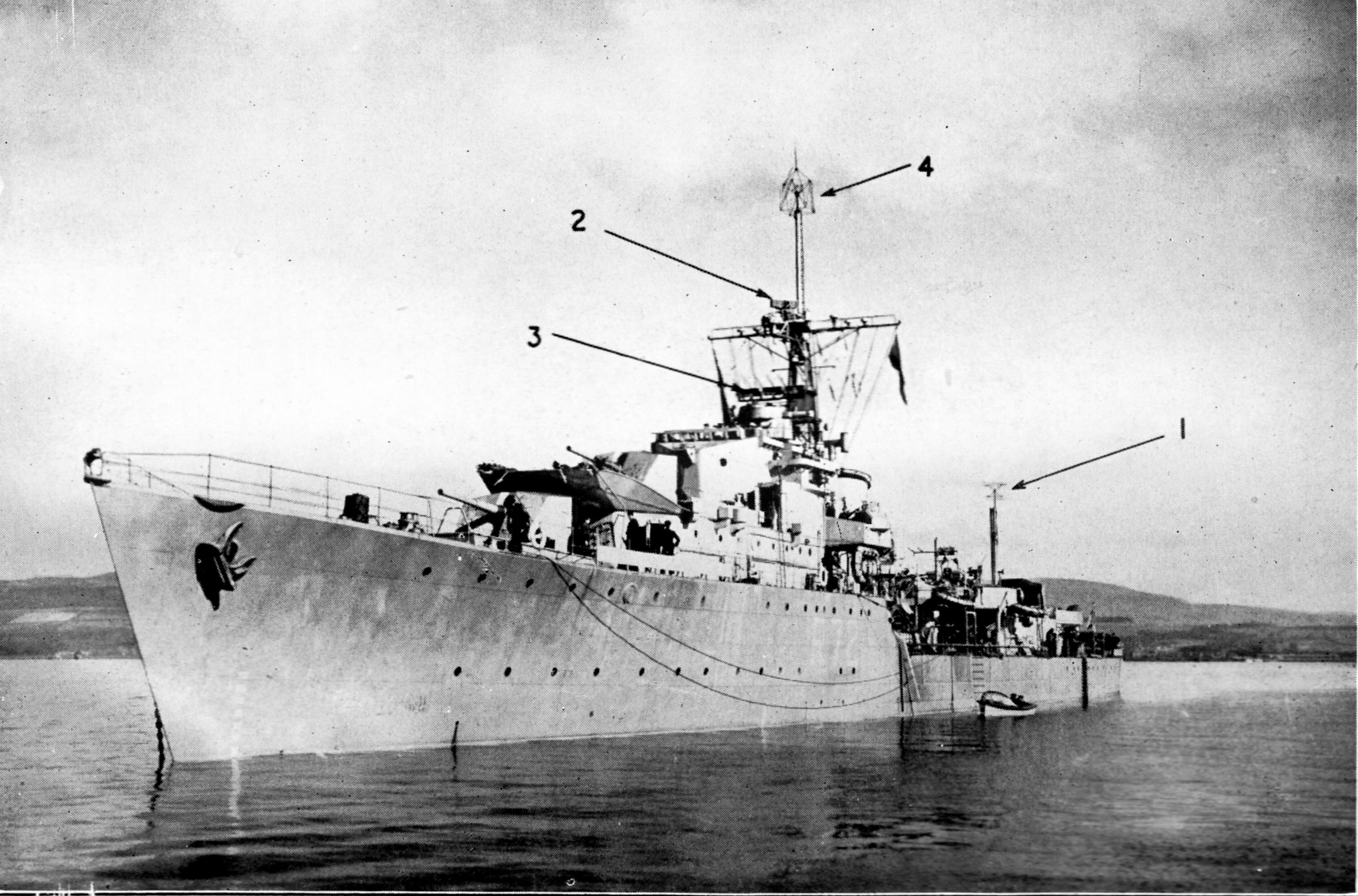
1.—WC type 291.

2.—WS type 272P on lattice mast (type 293 will replace 272P).

5.—H/F D/F.

3.—GA type 285.

also, 4.—R/T aerial.



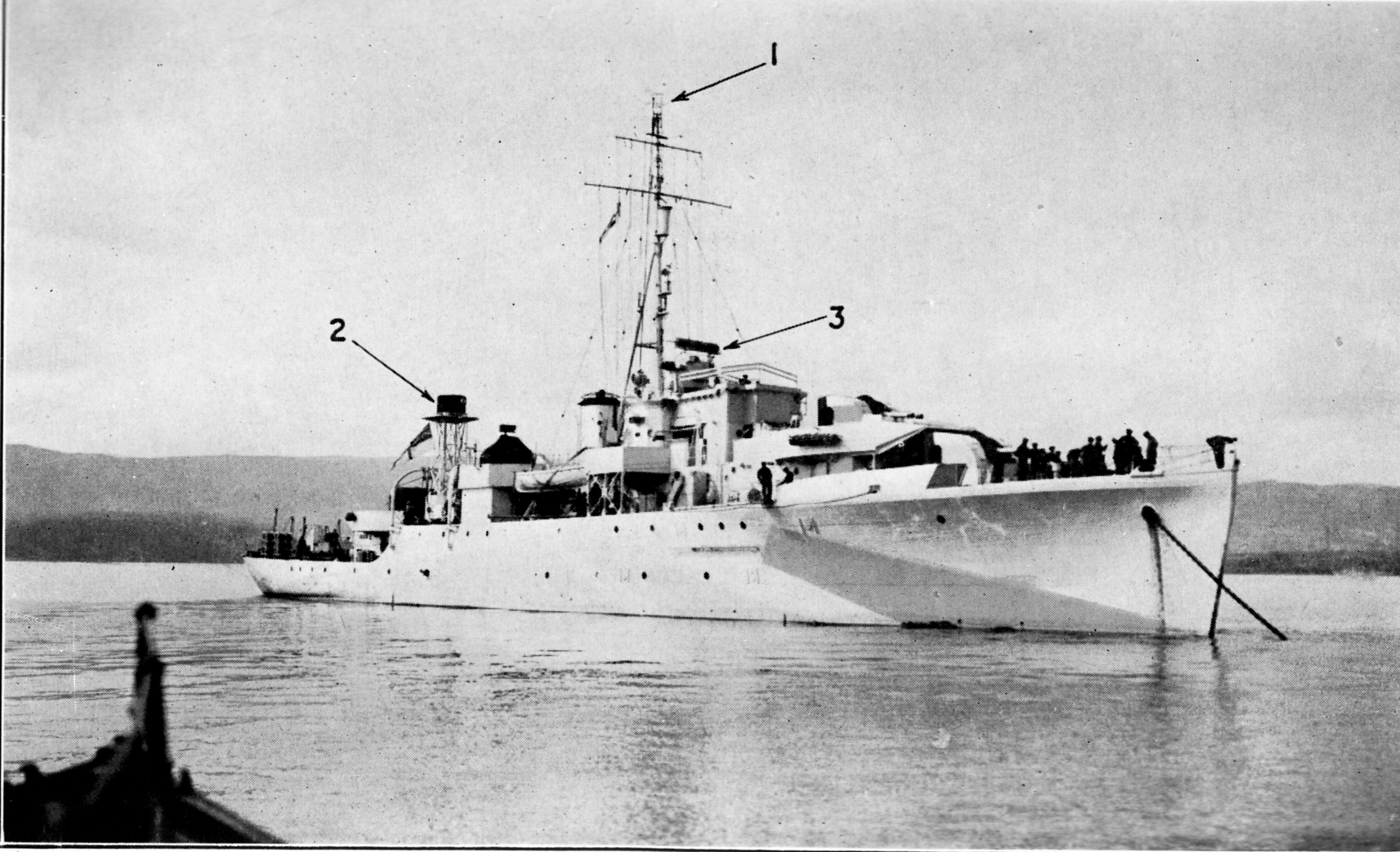
PHOTOGRAPH 41—Fleet destroyer (" Wizard ") with modern radar equipment showing :—

1.—WC type 291 aft.

2.—WC type 293 on lattice mast.

3.—GA type 285

also, 4.—H/F D/F

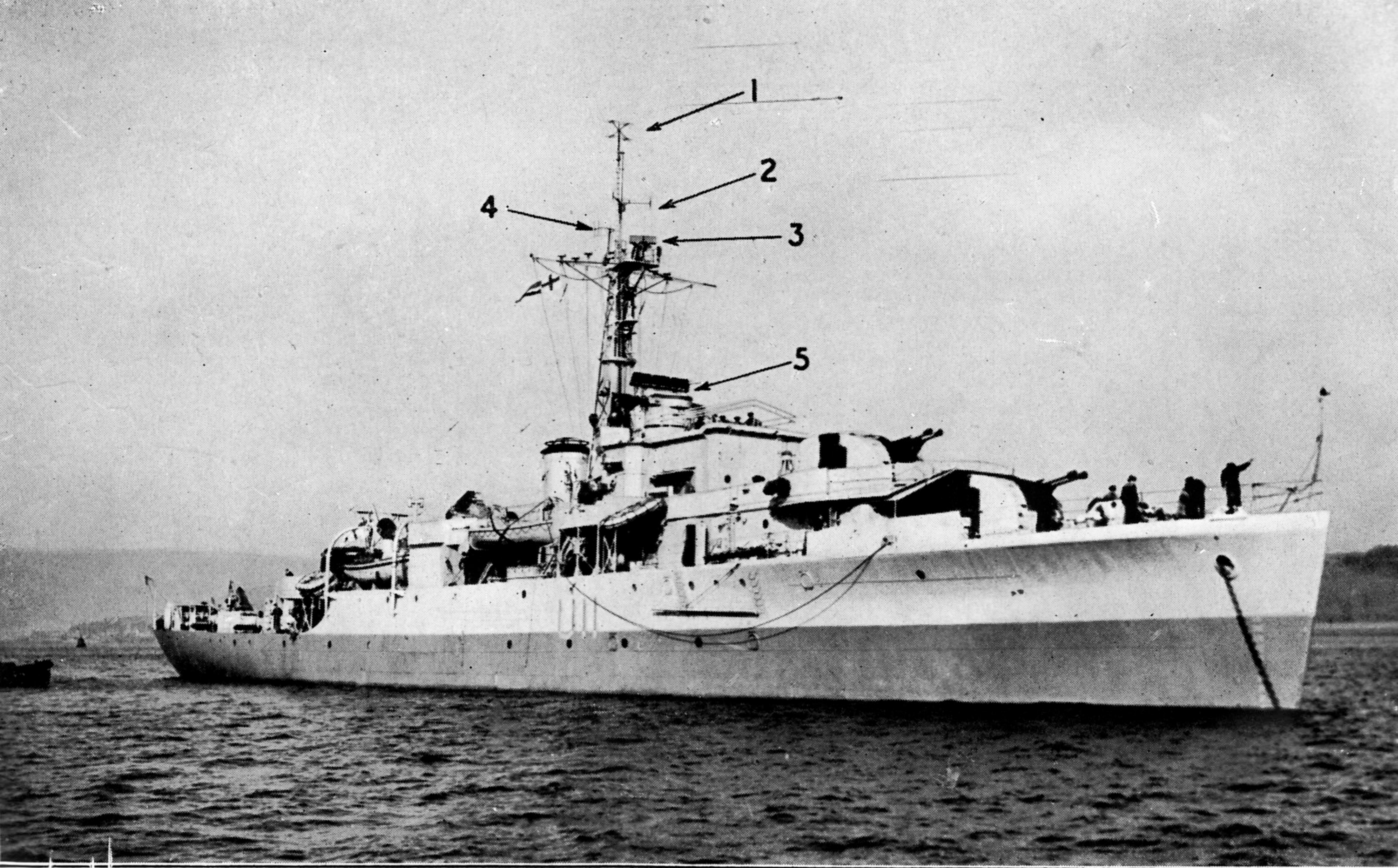


PHOTOGRAPH 42—A.A. sloop (" Woodcock ") with old radar equipment showing :—

1.—WC type 291.

3.—GA type 285

2.—WS type 272P.



PHOTOGRAPH 43—A.A. sloop (" Lark ") with modern radar equipment showing :—

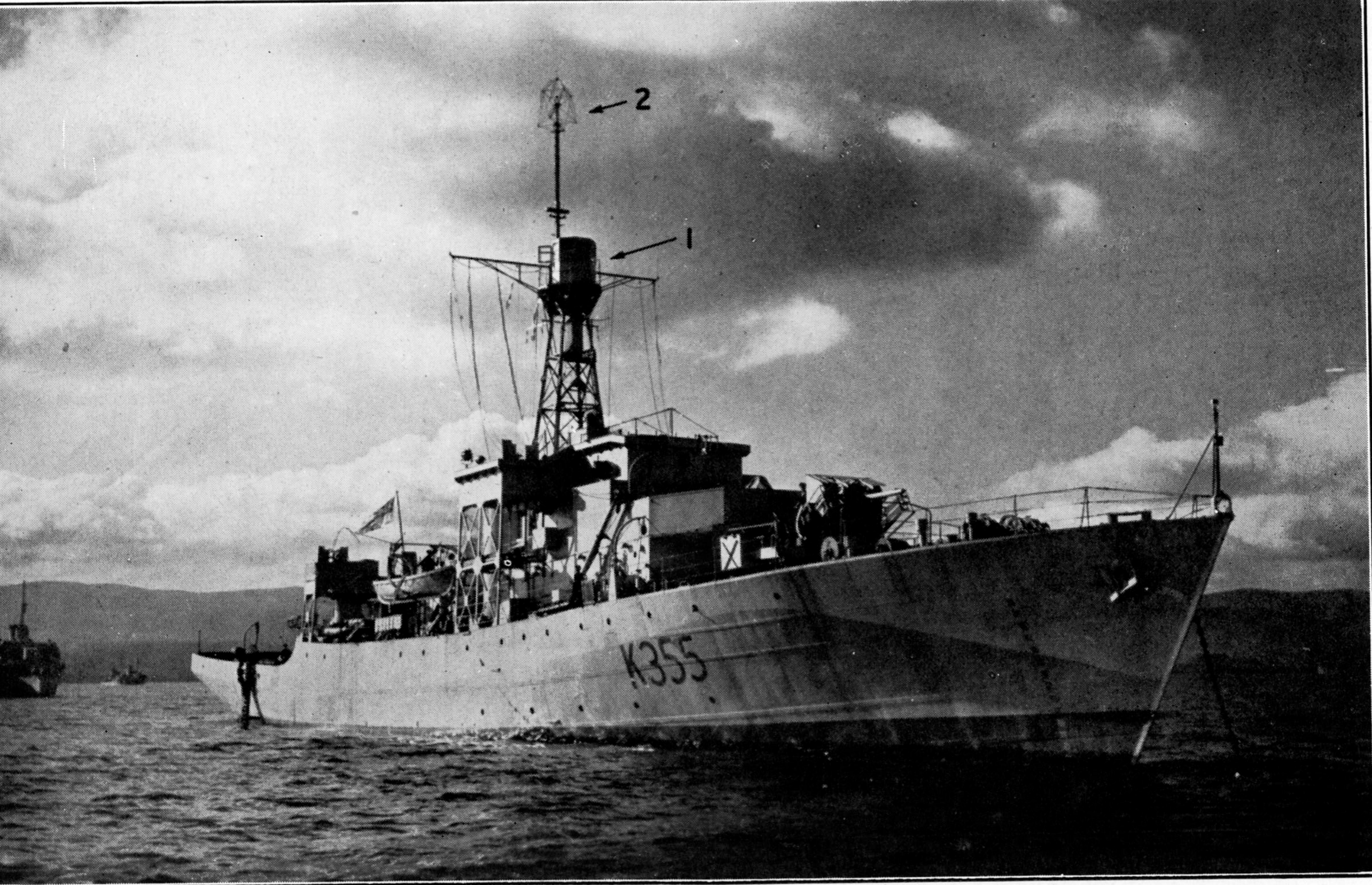
1.—WC type 291.

3.—WC type 293.

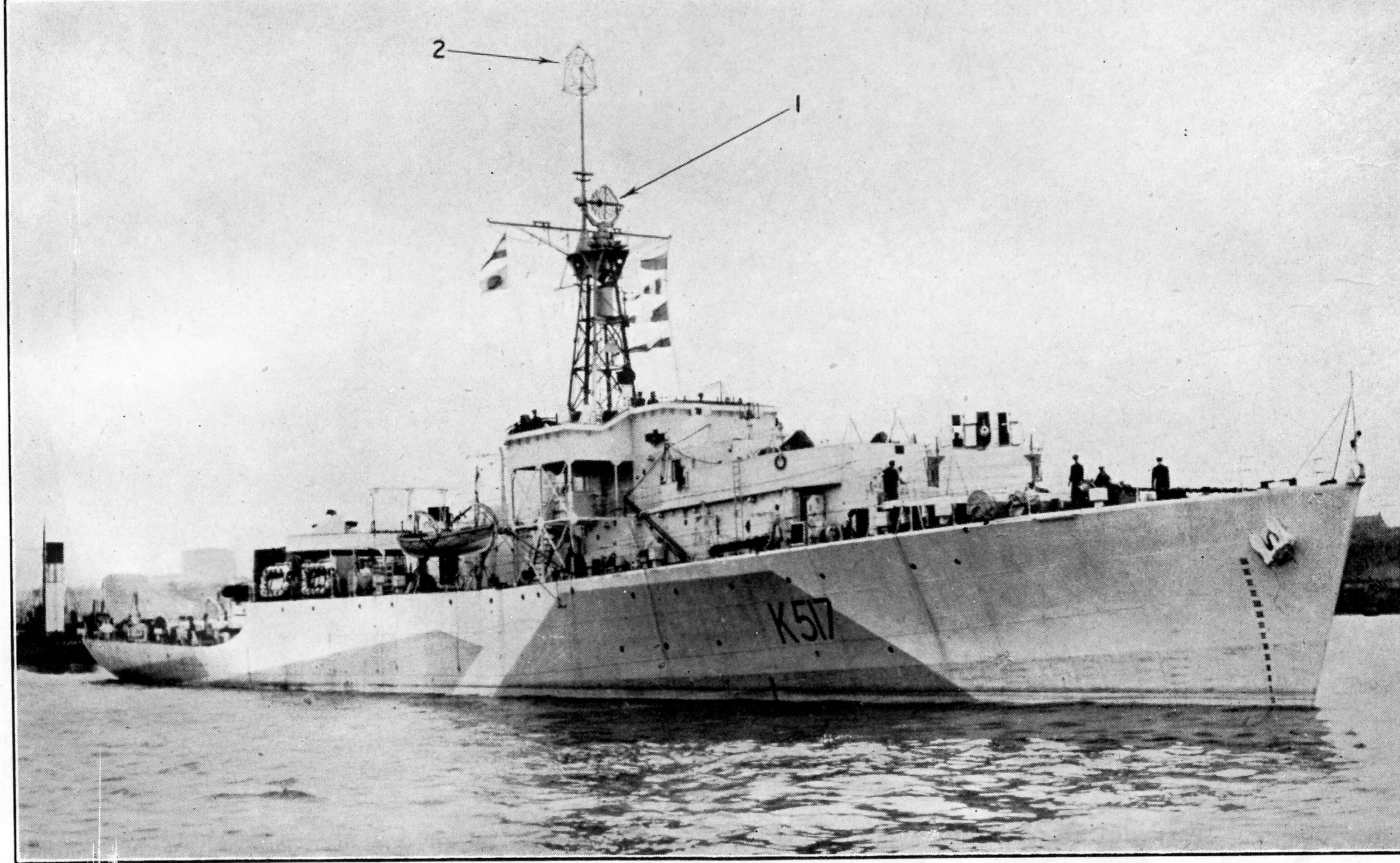
2.—All round interrogator type 242.

4.—Directional interrogator type 242.

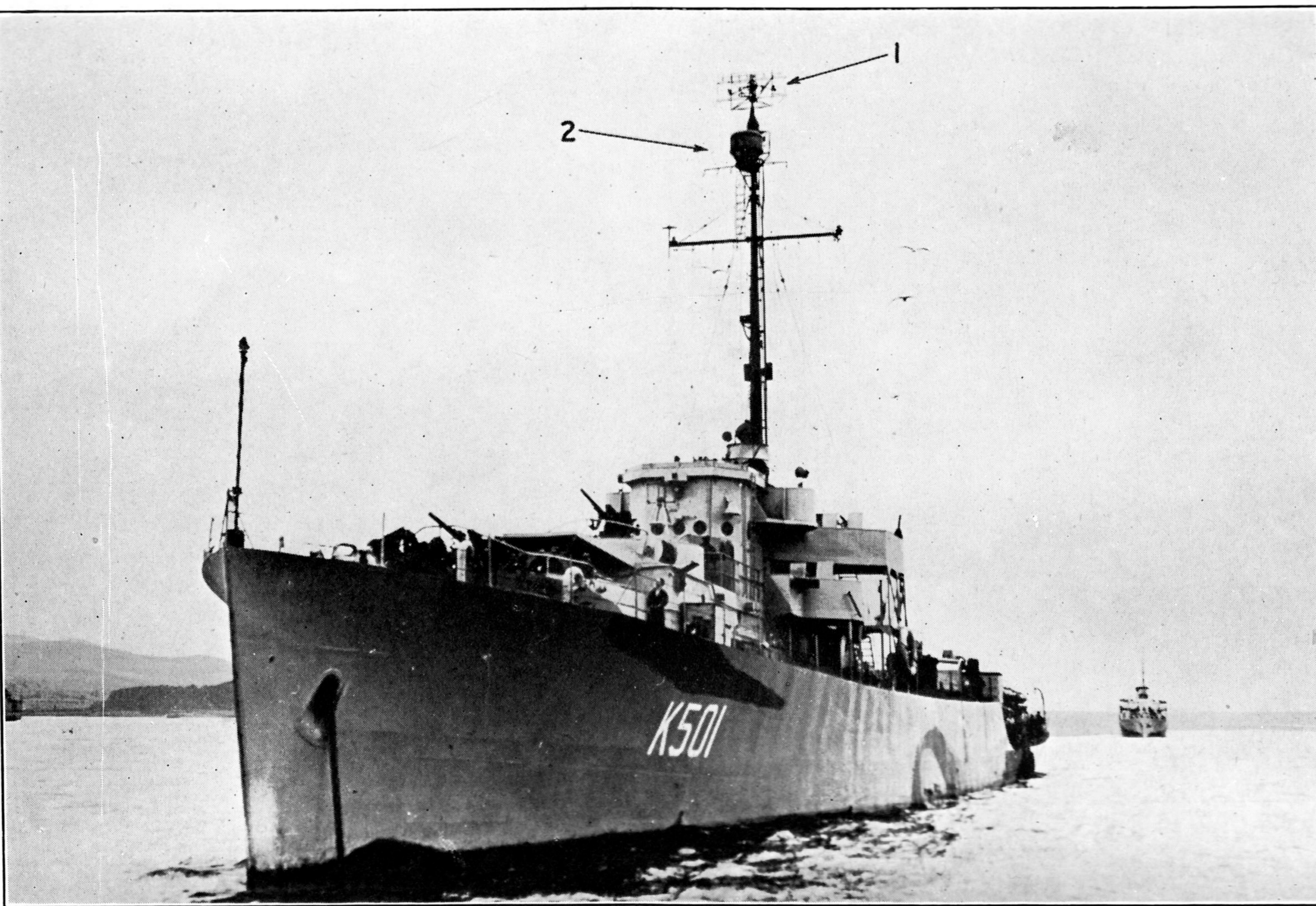
5.—GA type 285.



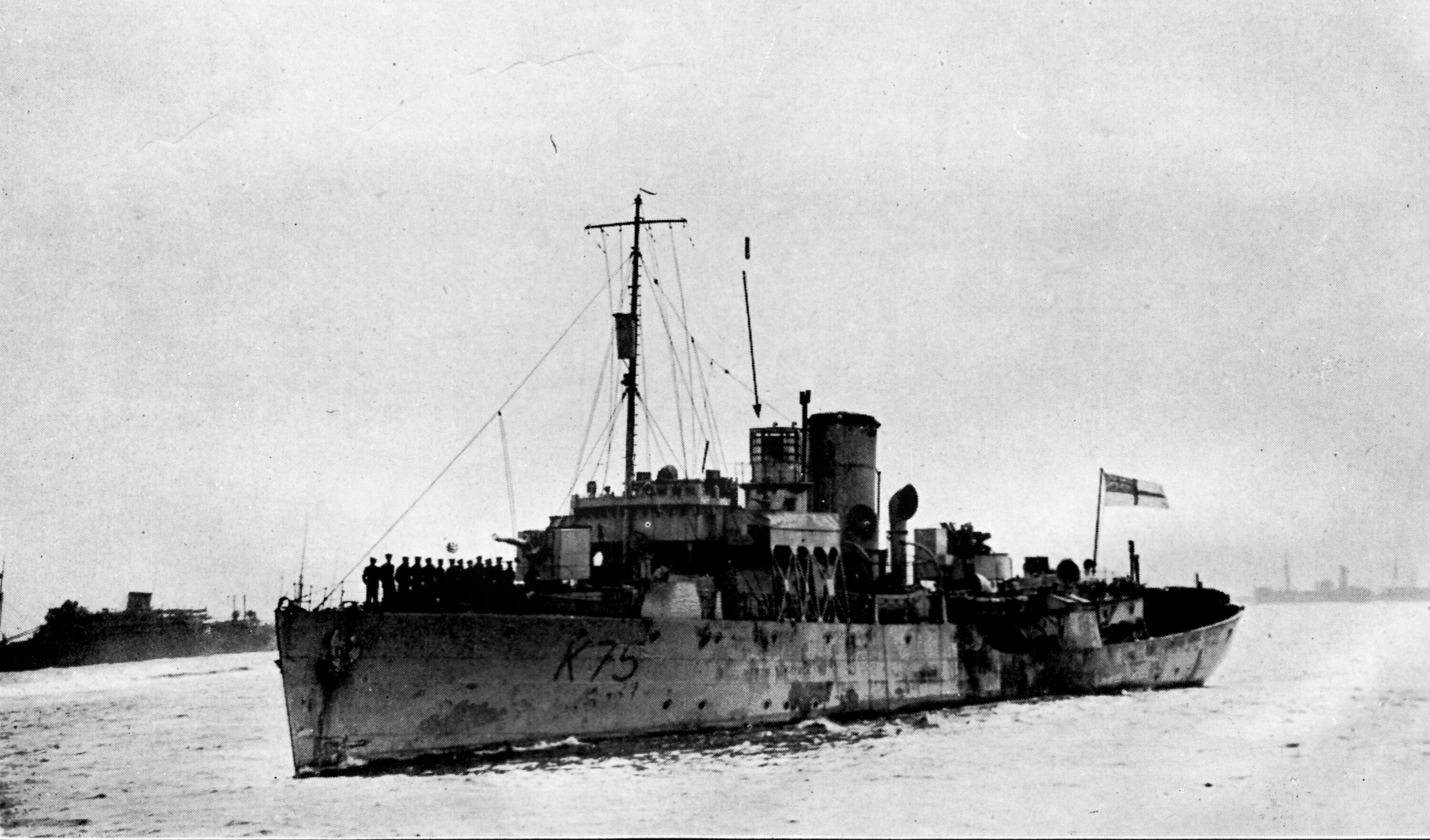
PHOTOGRAPH 44—Frigate ("Hadleigh Castle") in intermediate stage of radar equipment showing:—
1.—WS type 272P on lattice mast (to be replaced by type 277), also, 2.—H/F D/F.



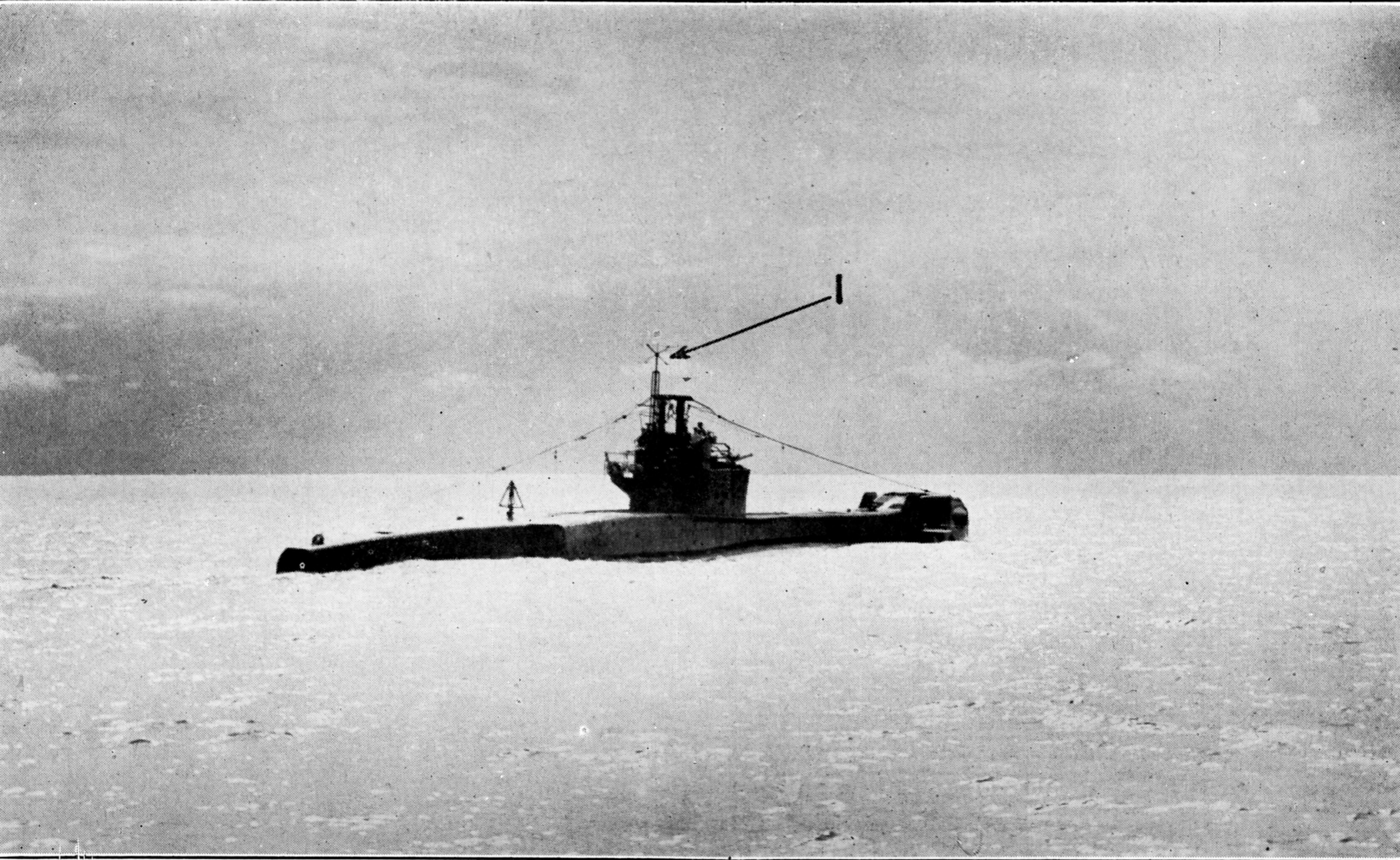
PHOTOGRAPH 45—Frigate ("Loch Morlich") with new radar equipment showing:—
1.—WS type 277, also, 2.—H/F D/F.



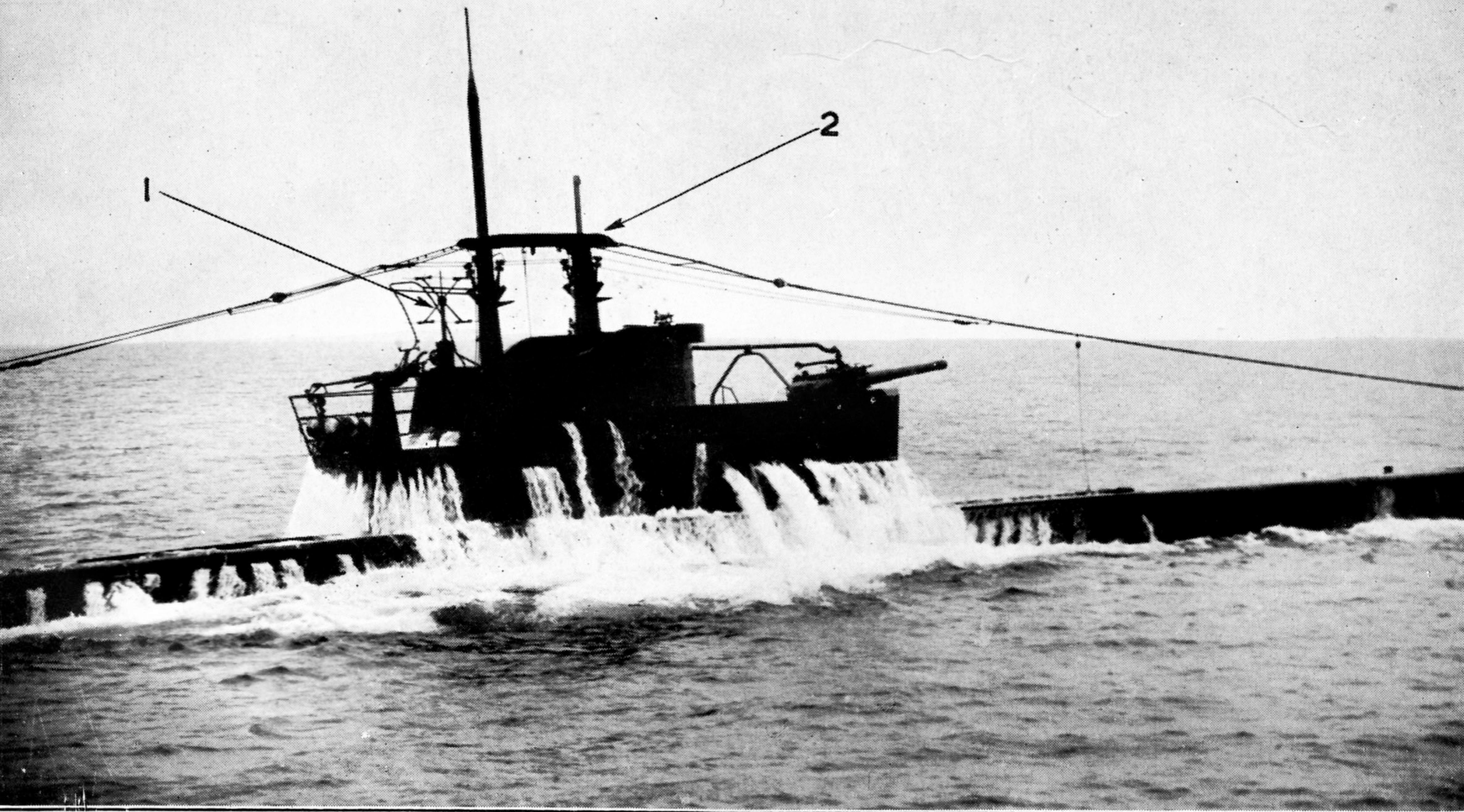
PHOTOGRAPH 46—Frigate ("Antigua") with U.S. radar equipment showing:—
1.—WC type SA. 2.—WS type SL.



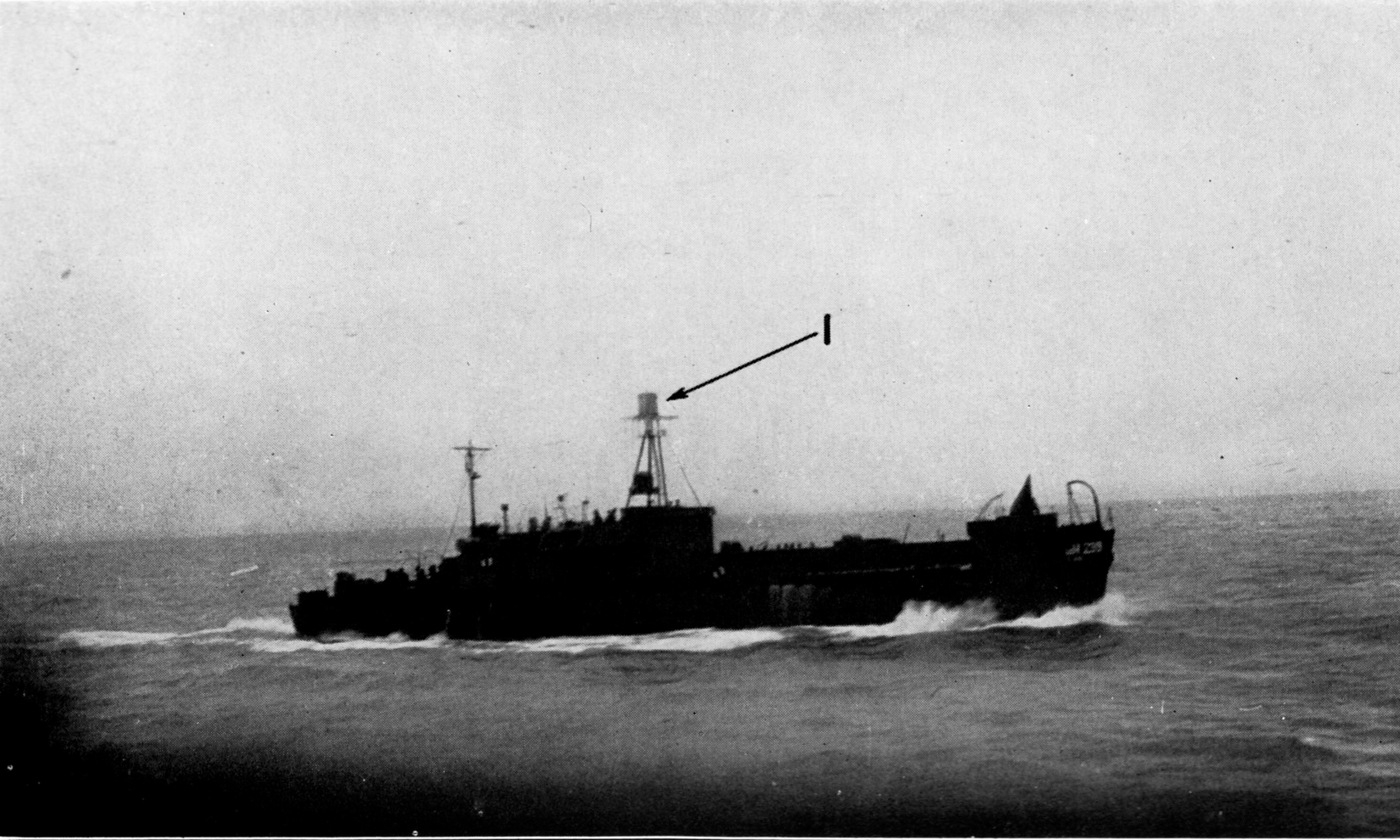
PHOTOGRAPH 47—Corvette (“Celandine”) showing 1—WS type 271Q.
(To be replaced by type 273Q.)



PHOTOGRAPH 48—Submarine showing 1—WC type 291W in raised position.



PHOTOGRAPH 49—Submarine showing 1—WC type 291W in housed position.
The surface warning aerial of WC type 267W will be mounted in position 2.



PHOTOGRAPH 50—L.C.H. showing 1—WS type 970.



PHOTOGRAPH 51—M.T.B. showing :—

1.—WC type 291U.

2.—Fixed directional interrogator type 242.

CHAPTER V

LIMITATIONS OF RADAR

1. Preceding chapters show what radar can do ; before reading how to use radar it is necessary to be quite clear what it cannot do, otherwise the user will have gained an unbalanced picture and perhaps be badly misled. Some of the limitations of radar have already been mentioned in *Chapter II*, but they are recapitulated here.

HUMAN FACTOR

2. This point is mentioned first deliberately. Radar is not an automatic instrument ; it requires to be operated intelligently. The best radar set in the world is little use in the hands of badly trained operators, or if the rest of the " team " in the Action Information Centre or Fire Control Room are ignorant of what radar can and cannot do. Training is dealt with in *Chapter XXII*, and it must be remembered that when operators first come to sea they have had little practical experience of operating.

3. Similarly, the correct procedure (drill) between the control position and the operator must be followed (*see Chapter XXIII*), or the radar reports may become actually misleading.

MAINTENANCE

4. When a new radar set is installed, it should be turned over in full working order. That, however, is only the beginning of the battle, for constant maintenance is required to keep it working properly ; even in 1944 a high proportion of the radar sets in the fleet are not up to full efficiency.

5. This problem is once again mostly one of the human element, for the maintenance personnel are often too few and are rapidly trained, and therefore have a difficult task to carry out all the routine tests and inspections which are necessary to *prevent* breakdowns occurring. The maintenance staff therefore should be left as free as possible and given all the assistance necessary. It may be unavoidable to have to employ them on other duties, but in this case full technical efficiency must not also be expected.

6. However, even if the maintenance staff do all that they can, occasional breakdowns are inevitable (*e.g.* from " dry joints " or burnt out valves). This is inherent in a complicated instrument developed rapidly in war-time. It is therefore of importance to keep always in mind what action should be taken if a radar set breaks down—there may be another set that can be used even if it is less suitable than the proper one.

LOCATION (=Range plus bearing)

7. Radar cannot detect objects under the sea, nor very much beyond the direct optical path and this limits the detection range of ships and low-flying aircraft. Also radar may not always detect objects inside optical distance if they are small, and such targets may be sighted first. Finally, aircraft cannot be detected when they are in the " gaps " of the vertical coverage diagram. For all these reasons, the alertness of visual lookout should not be relaxed because radar is being used.

8. The ground wave and wave clutter form a screen round the ship and unless special measures are taken make detection of aircraft and surface objects at close range difficult or impossible. The ground wave may extend to 4 miles or so in the case of WA sets using long pulse. In the case of WS sets, the ground wave is only about $\frac{1}{4}$ mile, but this may be extended by wave clutter to several miles on a rough day.

9. Range accuracy of radar is sufficient for most warning purposes, but for accurate ranging, such as is required in gunnery, sets must be calibrated, *vide Chapter XII*. Compared to range accuracy, bearing accuracy is not so good, varying from 1-2° for WS sets up to 5-10° for WA sets. Combined inaccuracy of range and bearing may result in an irregular plot particularly

- (a) When a target is at extreme range and the echo is weak and intermittent.
- (b) When there is a high rate of change of bearing of the target.

Under these conditions, it may take several minutes to obtain a plot which is smooth enough to deduce the targets course and speed with sufficient accuracy.

10. Gunnery ranging sets, which are fitted with beam-switching and very accurate ranging devices will, of course, give a good plot very much more quickly.

DISCRIMINATION

11. Owing to lack of range discrimination and bearing discrimination, particularly of WA sets, it is not always possible to distinguish between targets which are close to each other, nor sometimes even to tell that there is more than one target. Discrimination is most difficult when the targets are at very nearly the same range *and* bearing. The best discrimination is obtained by using a short pulse length, the shortest range scale, and by turning down the "input" when using P.P.I. or the "gain" when using "A" display, but these measures also have the effect of cutting down detection range and consequently reducing warning. More detailed remarks on discrimination and the advantages and disadvantages of P.P.I. and "A" display are contained in *Chapter VII*; in general the best discrimination is obtained by using "A" display but this, of course, means reducing all round cover and sacrificing plan display.

MAXIMUM RANGE

12. The first detection of a new target will not usually occur at the maximum range of which a set is capable. This is because at extreme ranges the echo is very small and often only appears intermittently. It may therefore easily be missed on several sweeps, by which time the target will have closed.

13. *Without P.P.I. display* it is necessary to sweep round comparatively slowly, stopping perhaps several times during each sweep to take bearings and ranges of targets already being watched. While doing this a new target which has come within radar range may have closed considerably before the sweep again reaches the right bearing. The trouble is accentuated if the target is a small one, whose maximum range is not great in any case, and the closing speed is high; in fact, when using an old set such as type 272P, the theoretical chance of detection of a U-boat before it comes into sight may be nil under unfavourable conditions.

14. Sets with broad horizontal beams, such as WA sets and WC type 291, can sweep much faster without fear of missing targets than can narrow beam (WS) sets not fitted with P.P.I. In general, it pays to sweep as fast as practicable except in small ships in rough weather, *vide para. 51*.

15. *With P.P.I. display* it is possible to sweep much faster, and this is normally done (usually automatically) so that a continuous picture is painted. This overcomes the disadvantages of narrow beams and slow sweeping and greatly improves the reliability of detection. When, however, it is desired to watch for fluctuating echoes, such as those from an aircraft or E-boat at extreme range, over a selected sector, it may be preferable to revert to hand training*. Provided the sector is a small one, this procedure will give a greater number of chances of seeing the echo and will, therefore, increase the probable detection range. Needless to say, all round warning will be lost while the sector sweep is in force.

Effect of inclination

16. With surface warning sets the inclination of the target makes a considerable difference to the height of echo at extreme range and therefore to the maximum range obtainable. As might be expected, better maximum ranges are obtained against targets beam on as the reflecting area is then greatest. With aircraft warning sets the inclination of the aircraft target also affects results; a closing target gives a bigger echo than a similar target opening at the same range and targets of the same type are therefore detected at greater ranges when closing than when opening, always provided that the aerial is pointing in the right direction at the right time.

Aerial stops

17. The older types of radar (except type 291) cannot be rotated continuously because of aerial stops, which are usually placed aft. These limit the sweep to 400°, which means that the aerial must be rotated first clockwise and then anti-clockwise. This, of course, tends to increase still further the chance of a closing target not being picked up straight away, particularly if it is on an astern bearing. Also with WA sets, the aerial stops make the taking of bearings astern slow and difficult.

Siting

18. The ideal is for all warning radar sets to have an all-round view, but this would require several masts or structures each higher than all the others which is clearly impossible. Warning radar sets therefore usually have a blind arc, and its extent should be well known like the "A arcs" of the guns. Where possible warning radar sets should be sited so as to be complementary, *e.g.* type 277 with a clear arc forward and type 293 with a clear arc aft.

* *Note.* The expression "hand training" includes the use of slow or creeping speed with WS type 277. "Hand training" usually infers sweeping from side to side as opposed to continuous (and if possible automatic) rotation of the aerial.

HEIGHTFINDING

19. Shipborne radar is unable to measure the height of aircraft with the same precision as it measures range and bearing, nor is a change in height quickly detected. At present, the average error obtained with WA sets is of the order of 1,000–2,000 feet. With practice, it may be less, but it may also be a great deal more. WC sets cannot effectively measure height. The fitting of centimetric stabilised elevation finding sets (SM1, SP, and types 277 and 981) will improve the accuracy and reliability of heightfinding. Heightfinding is discussed fully in *Chapter XI*.

CLASSIFICATION AND IDENTIFICATION OF ECHOES

20. By classification is meant distinguishing between the echoes from different kinds of targets and by identification is meant distinguishing between friendly and hostile targets.

Classification of echoes

21. By the form of the echo shown on "A" display it is usually easy to differentiate between ships, aircraft and land, and the plotted relative movement of the echo should clear up any doubt which exists. It is not, however, so easy to determine the number of aircraft in a body. A good operator will be able to tell the difference between a "single," a "few," and a "group" (*vide Table 3*), but he will seldom be able to do better than this, and there is always a tendency to report a "single" as a "few," especially if the target is a large aircraft.

22. On P.P.I. all echoes appear of equal consistency, owing to the effects of the "limiter" and the after-glow tube. It is, therefore, only possible to distinguish between ships and aircraft by their movement, and the number of aircraft in a body cannot be counted. Land can usually be distinguished by its contour or irregular shape.

23. The size of ship targets may under *normal* conditions be estimated by the initial detection range (assuming, of course, that an all-round sweep is in force). But this method cannot be used under anomalous conditions; *vide paragraphs 54 to 56*.

24. Operators may also confuse cloud echoes with land echoes or formations of aircraft; and decoy balloons may be mistaken for U-boats, *vide paragraph 47 (b)*.

Identification between friend and foe

25. The Radar Recognition or I.F.F. system provides a radar means of distinguishing between friendly and hostile detections, and non-radar evidence may also assist as explained in later chapters. The radar recognition system, however, is not infallible, *e.g.* :—

- (a) The I.F.F. (or the Interrogator) may not be working efficiently.
- (b) The I.F.F. may not be switched on, or may not be fitted.
- (c) The I.F.F. may become saturated if too many interrogators are trained on it. In a big operation it may be even necessary to "ration" the use of I.F.F. to avoid the whole system becoming useless.

26. I.F.F. must therefore be regarded as being an *aid* to recognition—useful when it responds, but not positive proof of hostile nature if it does not.

27. There is also always the possibility of the enemy simulating our I.F.F.

FALSE OR UNWANTED ECHOES

28. There are, unfortunately, quite a large number of kinds of false or unwanted radar echoes or forms of interference which are obtained from time to time and which confuse the radar display and slow up reporting, even if they do not actually confuse the situation.

Land echoes

29. These are naturally worse closest to the land, and with WA sets may be troublesome up to 20 miles or more off shore. They are made worse by the fact that numerous side echoes and back echoes may be obtained off large land masses. Clearly, land echoes are most troublesome with wide beam (WA) sets, and least troublesome with narrow beam (WS and centimetric WC) sets. Use of short range scale and short pulse length helps to reduce land echo confusion, and when operating near the land it is often wisest to go for good discrimination rather than maximum range.

30. P.P.I. has the advantage over "A" display that it is easier to follow the movements of targets amongst the land echoes.

Side echoes

31. Side echoes are caused by the subsidiary beams of a radar set. They are distinguishable by the fact that they appear at equal angles either side of the true echo. They are worst when detecting large targets at close ranges and can be reduced or eliminated by turning down the input or gain, *but this deprives the ship of warning of smaller targets at greater ranges*.

False bearing echoes

32. False bearing echoes are caused by reflections off own ships superstructure or rigging, and are worst with high powered centimetric (WS and WC) sets.

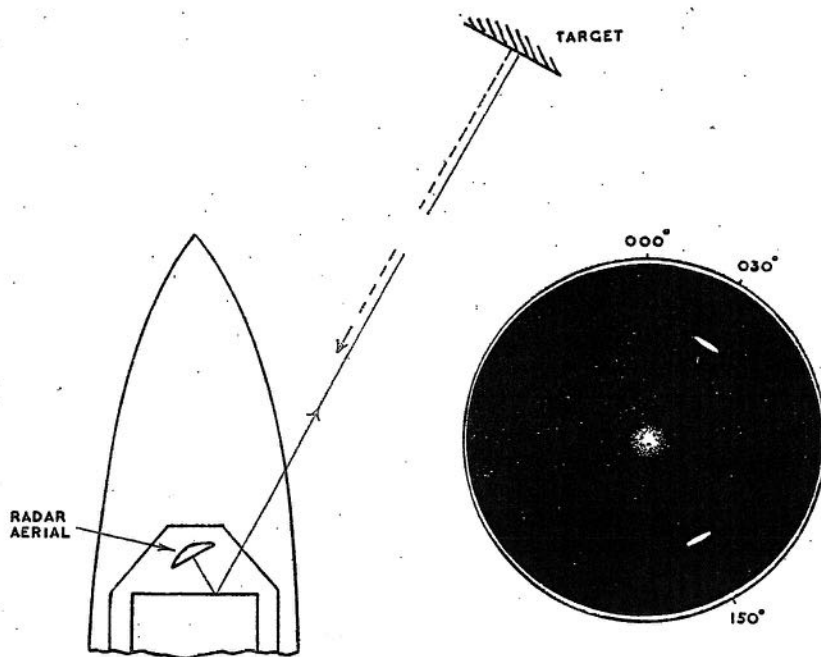


Fig. 21—Showing cause of false bearing echoes due to reflection off superstructure or rigging. As the radar aerial sweeps, two echoes—one true, one false—may be painted on the P.P.I.

It will be seen from Fig. 21 that with the aerial bearing 150° an echo may be received from a target which is really bearing 030° . So two echoes of the target will appear on P.P.I. as the aerial sweeps, as shown.

33. False bearing echoes may be spotted as such :—

- (a) because they appear at exactly the same range as the true echo ;
- (b) because they usually appear on the same *relative* bearing, i.e. on the bearing where the superstructure or rigging is nearest or gives most reflection ;
- (c) because if the ship alters course, the true bearing of the false echo will alter, while that of the target will not.

34. Unless the set can be resited, the only way of reducing false bearing echos caused by halliards and W/T aerals in the way of the radar beam is to remove them (particularly, of course, on ahead bearings). The minimum requirement for type 271Q is that not more than two stays, halliards, etc., should be " illuminated " at any given time by a 6 feet wide beam at the centre-line of the aerial system and within a 12 feet radius of it. The requirement is more stringent for types 277, 276 and 293 which are of higher power.

35. False bearing echoes caused by the funnel or superstructure may be reduced by means of a wire-mesh screen, placed so that it will reflect the beam upwards instead of horizontally. The screen will, however, only be effective if it can be placed more than 10 feet from the centre of the aerial.

Double reflection

36. At close ranges, and particularly with high-power centimetric sets, double reflection may take place. The cause and effect is obvious from *Fig. 22*, and such false echoes should be distinguishable by the fact that they remain at twice the range of the target and on the same bearing even if own ship alters course. Also, on "A" display, the second (false) echo will be smaller than the true echo because it has been reflected from three surfaces instead of only one.

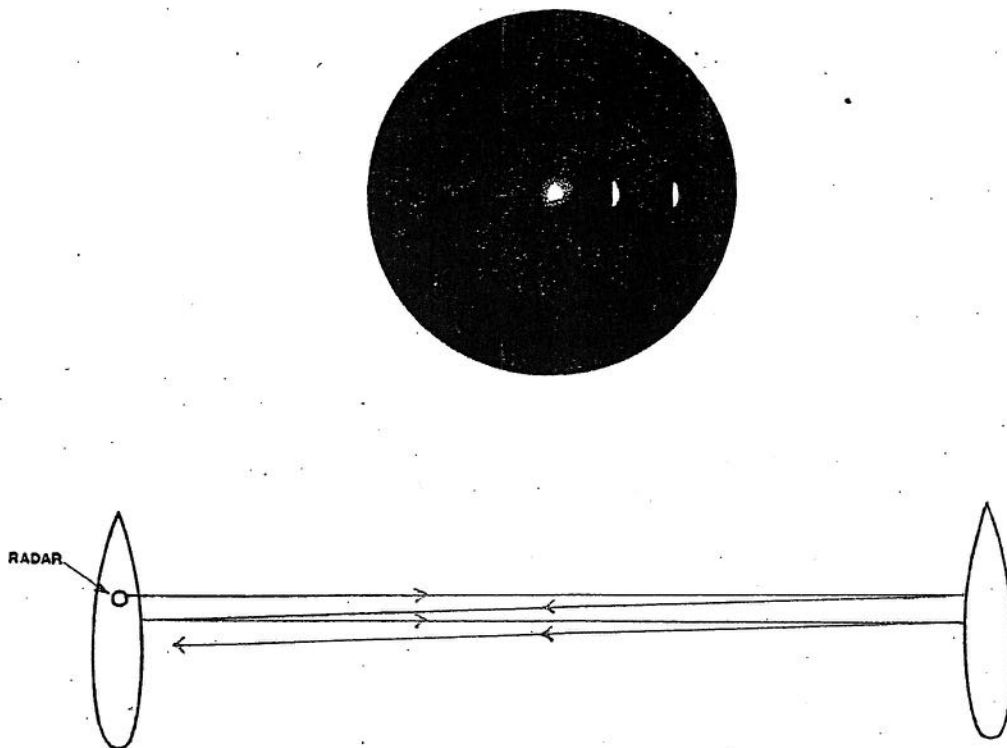


Fig. 22—Showing cause of "double reflection." Sometimes obtained with centimetric and decimetric radar sets at close range. Two echoes are painted on P.P.I., on the same bearing, the false echo appearing at twice the range of the true echo.

Rainclouds and Cold Fronts

37. Rainclouds including thunderstorms give echoes rather like a large land mass, but the echoes are less distinctive and their individual positions change frequently. The result on P.P.I. looks like a rather blurred picture of land, and is sometimes confused with it to the detriment of navigation, though turning down the input may enable the land and cloud echoes to be differentiated. Cold fronts may sometimes be distinguished on a P.P.I.

Birds

38. Flocks of birds and even single big birds such as the gannet have frequently given echoes. These are usually weak and fluctuating, and may be identified by plotting since a bird is faster than an E-boat and slower than an aircraft.

Ground wave and wave clutter. Watson effect

39. The cause of ground wave and wave clutter has been explained in *Chapter II, paragraphs 40-42*. They make it difficult or impossible to follow echoes close in, and therefore form a sort of screen round the ship. This screen has a minimum range determined by the ground wave and a maximum range determined by the wave clutter which may extend to some miles in the case of high-powered highly sited WS sets on a rough day.

40. Large echoes can be followed further in by reducing the input or gain, but as usual this cuts down detection of targets at greater distances.

41. With WS and WC sets, when using "A" display, a very strong echo can be followed almost right into the ship by making use of **Watson effect**. This is achieved by turning the gain of the receiver well up, when a split will be seen at the peak of the echo. The split will increase as the gain is turned up still further, and a bright spot will appear at the base of the split. The bright spot represents the echo of the target, and accurate bearings and fairly accurate ranges can be taken even after the spot has merged into the ground wave.

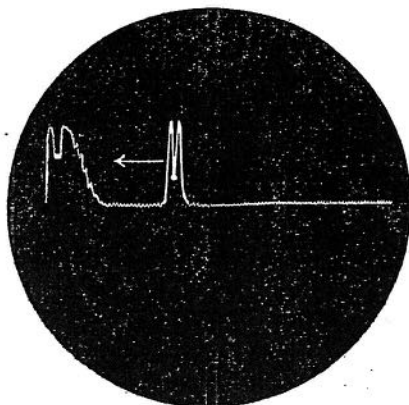


Fig. 23—Showing the use of "Watson effect" on "A" Display. By turning up the gain the echo becomes split and a bright spot may appear which can be followed into the ground wave.

42. Watson effect cannot be used with P.P.I. On the other hand, it is easier to follow the movement of echoes among wave clutter when using P.P.I., since the wave clutter appears as irregular patches whose shape changes each paint, while the position and consistency of the target echo remains appreciably the same.

Interference from friendly radio transmissions

43. W/T and R/T transmission (including W/T beacons) in own ship or in the vicinity may cause serious interference. R/T is usually the worst. The trouble can be alleviated by a suitable choice of communication wavelengths, or sometimes by resiting the communication aerials. Little can be done at the radar end, as the wavelength and aerial position are fixed, though special "filters" have proved useful in some cases.

44. Equally, radar can cause serious interference with communications. To reduce this a device known as a Radio Interference Suppressor (R.I.S.) is fitted to most communication receivers.

45. Other radar transmissions using the same wavelength can sometimes be observed on the radar trace. On "A" display they appear as evenly spaced vertical lines moving across the screen. On P.P.I. they appear as evenly spaced spirals emanating from the centre. They rarely cause interference to operating, and the effect can sometimes be made use of to obtain bearings of friendly units.

Enemy counter-measures (see also Chapter XV)

46. **Jamming**, *i.e.* deliberate radio interference by the enemy, may appear in a number of different forms, as illustrated in Chapter XV, Fig. 64. Jamming can sometimes be countered by a slight shift of wavelength or by anti-jamming devices fitted to some old sets and all new sets. The net effect of the enemy's effort will vary between wide limits.

47. The enemy may also use **non-radio methods of interference** in the form of reflectors. The two main kinds so far met are:—

- (a) "**Window**," which consists of a large number of metal foil strips (a familiar feature in South-East England during the raids early in 1944). These are cut to length so as to be good reflectors (*i.e.* "dipoles") at the estimated wavelength of the radar to be jammed, and form a cloud or "infected" area through which it is difficult to follow targets and behind which they may not be detected. Centimetric WS sets are often least affected by "Window," because of their good discrimination. The effect of "Window" is illustrated in Chapter XV, photographs 70 and 71.
- (b) **Radar Decoy Balloons (R.D.B.)** are used by U-boats to mislead escorts. Their construction and the extent to which they can confuse WS sets used for U-boat detection are described in Chapter VIII, paragraphs 11 to 13.

48. An R.D.B. will travel down wind at about two-thirds wind speed, so plotting should often be able to classify the echo as "Decoy."

EFFECT OF THE WEATHER AND ATMOSPHERIC CONDITIONS

49. Weather and atmospheric conditions may affect radar in a number of ways as described below.

Rough weather

50. The narrow beam of a centimetric (WS) set may be lifted right clear of the horizon when a ship rolls or pitches. This seriously limits the value of earlier WS sets (e.g. type 272P), especially in small ships against small targets whose echoes become intermittent or are missed altogether. To counter this in later sets either:—

(a) The vertical beam is made wide enough to allow for all reasonable conditions, e.g. it is 20° in type 276.

Or (b), the set is stabilised, as in types 271/3Q and 277.

51. Further, the swell may actually obscure the line of sight between a small target such as a U-boat and a small ship where the WS radar set is mounted low down. In these circumstances it is necessary with old WS sets to sweep very much more slowly than the normal rate to make certain of detecting small targets at all, which, of course, reduces the probable detection range. With modern WS sets, however, the sweep rate should, if anything, be increased. The object in all cases is to avoid coinciding with the period of the swell which normally corresponds to a sweep rate of about 4 r.p.m.

Atmospheric conditions

52. Under certain conditions of the electronic atmosphere **anomalous propagation** exists. It is particularly common in hot climates on sultry windless days, but is not uncommon even in the United Kingdom, especially in summertime. It is rare on cold and windy days.

53. The effect on *surface detection* is to give exceptional ranges, particularly with high power centimetric sets (types 271Q, 276, 277, 293 and SG). Ranges of over 50 miles on medium-sized ships have been known. Of course, this is an advantage rather than a limitation while it lasts. The danger is that one may be led to expect results which are exceptional and not normal. It must be appreciated that even if anomalous conditions persist for several days—as they commonly do—results will sooner or later return to normal. There is no ready and certain means afloat of forecasting anomalous conditions, though some success has been achieved at shore radar stations. If it could be done, it would clearly be an important consideration when planning.

54. One way to recognise anomalous results is by observing the behaviour of the echo as the target closes (keeping the gain constant). Normally, the height of a ship echo rises evenly as shown in *Fig. 24*. The dotted line shows an anomalous detection, and it will be seen that the echo height fluctuates or even disappears at anomalous ranges before finally picking up its right "curve."

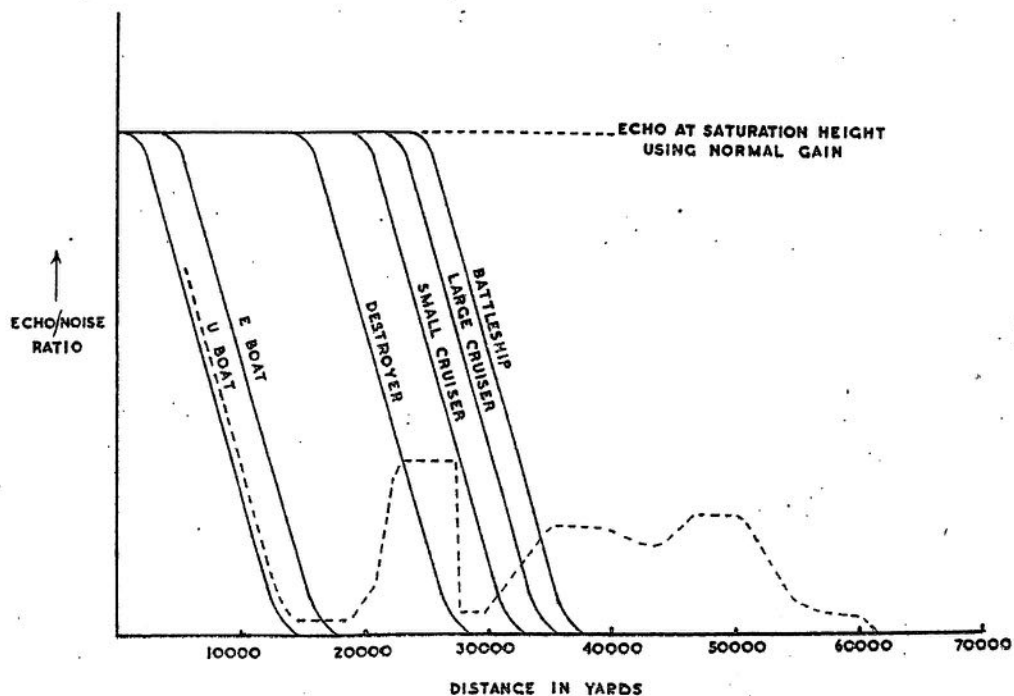


Fig. 24—Showing the effect of anomalous atmospheric conditions on detection range. The figure is based on Surface detection by WS type 273Q at 65 feet, and the normal detection curves for different sized targets are shown in black. These rise nearly uniformly to saturation as the range decreases. Typical anomalous detection of a U-Boat is shown in red.

55. This method if worked up should prove of value in spotting anomalous detection and unless anomalous conditions are carefully watched for and understood, it will be impossible to use the initial detection range method (*para. 23*) as a guide to the size of the target detected.

56. The effect of anomalous conditions on *aircraft detection* whether by WA or WS sets is to fill out the lower part of the lowest lobe. This increases the detection range of low and medium aircraft, but at the same time spoils heightfinding by first detection method (*Chapter XI*). Results against high aircraft are not affected.

57.

INTERCEPTION AND D/F

58. Since radar is a radio transmission it can be intercepted and D/F'd, in the same way as W/T. It is, however, much less "dangerous" than W/T because of the very short wavelengths used and the fact that the energy is concentrated into a directional beam instead of being an all-round transmission.

59. **Interception**, which means actually picking up a radar transmission, is not easy, particularly at the shortest (*i.e.* centimetric) wavelengths, and judging from our own experience there are likely to be frequent "false alarms" including those due to local interference. Furthermore, radar sets even of the same type are not on exactly the same wavelength, so that the enemy has to search over a waveband. This requires a special operator, or more probably several operators in watches.

60. Then again the radar beam is normally kept sweeping round, and it is therefore necessary that the moment that the enemy operator is on, the right wavelength should coincide with the period during which the radar beam is trained on him. This again reduces the chance of interception.

61. Assuming, however, that the enemy is keeping watch, it is necessary to know the sort of ranges at which interception might be possible. Unfortunately, it is not practicable to give precise figures, as these are affected by so many factors, the chief of which are:—

- (a) the wavelength, power and height of the radar set. Of these the wavelength is the predominant factor;
- (b) the technical development and operating efficiency of the enemy's interception organisation. In a ship, laboratory standard is not achieved;
- (c) whether atmospheric conditions are normal or anomalous.

62. The following table gives guidance figures which cover most of these factors. Unless there is special need for security, it is recommended that the figures normally used should be those from column one, which is based on the efficiency of our own interception receivers. Should the enemy concentrate his effort on interception, the figures in column two could be achieved, though a figure somewhere between columns one and two is more likely. Column three gives the likely maximum figures under anomalous conditions (*paragraph 52*).

63. Guide to interception ranges of radar.

CLASSIFICATION AND TYPE OF RADAR SET		RANGE IN MILES		
		COLUMN 1 RANGE THAT COULD CERTAINLY BE ACHIEVED IF ENEMY IS LISTENING	COLUMN 2 POSSIBLE RANGE IF ENEMY ATTAINS HIGHLY DEVELOPED EQUIPMENT AND ORGANISATION	COLUMN 3 POSSIBLE RANGE UNDER CONDITIONS OF ANOMALOUS PROPAGATION
WA sets	79 } 279 }	150	250	250 (*See note)
	281	100	200	200 (*See note)
1½ metre WC sets	291	40	75	100
Interrogators	242 } 243 }	10-20	50	100
50-cm. Gunnery sets	282 } 283 } 284 } 285 }	20-25	50	100+
10-cm. WS and WC and Gunnery sets	272P } 271Q } 273Q } 274 } 275 } 276 } 277 } 293 }	25	45	100+
3-cm. sets	262	20	35	Not known
	267W } 268 }	20	30	Not known

* *Note.* Anomalous conditions will not materially affect the direct interception of metric sets. Spasmodic indirect reception at long distance may, however, be possible by day, particularly in the summer, over small and changing areas. Typical distances for type 79/279 are 600-800 miles and 1,200-1,500 miles. With type 281 the occurrence is less frequent and will be at distances outside 1,500 miles.

64. The figures given in *paragraph 63* are for normal ship-ship heights of aerial. Interception range of or by aircraft, special balloon, or a high shore station may be two or three times as great. In addition, a shore station is likely to be fitted with more efficient receiving gear.

65. *Radar Beacons* if triggered could also be intercepted, the surface range corresponding to type 242. *I.F.F.* could be intercepted, but this is very unlikely owing to its short-intermittent transmission. Neither *Radar Beacons* nor *I.F.F.* transmit unless actually triggered.

66. One factor which affects the likelihood of interception is whether the enemy knows we are using a particular waveband. This is why it is important to deny the enemy knowledge of new radar wavelengths, *e.g.* by avoiding publishing photos of aerial or reflectors from which he can measure or guess the wavelength. This is even more important for radar than for W/T because the wavelength of a given radar set cannot be altered very much, if at all.

67. It must be assumed, however, that the enemy is now aware of the wavelength of all our older sets, *e.g.* WA types 279 and 281, WC type 291, and the 50 cm. gunnery series (types 282-3-4-5). There is also some evidence that he knows that ships use 10 cms. (WS, WC, and GS sets).

68. Enemy interception receivers may be used to estimate the distance and movement of our ships and aircraft by the strength of received signal, and whether it is getting louder. This is, however, a very inexact science and our aircraft have means of countering it (*see Chapter XVIII*). Also, anomalous conditions may entirely upset range estimation.

69. **D/F.** Even if the enemy succeeds in intercepting radar, he must still get its bearing if the information is to be of much tactical use to him. This is not difficult for shore stations to do, but it is not nearly so easy from a ship as it requires an aerial, perhaps of some size, and a good clear site which is usually hard to find except at the expense of equipment which may be considered more useful such as radar itself. Even if a directional aerial is fitted, it will often only be possible to estimate bearing to the nearest quadrant, or by pointing the ship.

70. **The combined interception and D/F risk** may therefore be summed up as follows :—

- (a) Interception is not easy, and bearings if taken are likely to be inaccurate, especially from ships.
- (b) The shortest wavelengths and narrow beams are safest.
- (c) The newest wavelengths are safest.
- (d) Sweeping makes the enemy's task harder.

PART II

THE USES OF RADAR

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CHAPTER VI

ACTION INFORMATION CENTRE AND ORGANISATION

Before proceeding, in succeeding chapters, to the various uses of warning radar it is convenient to describe briefly the layout of the Action Information Organisation which uses and controls it. A full description is contained in *C.B. 04357 Action Information Centre*.

2. In the early days of radar rough and ready means were used to dispose of radar information. Indeed, it was not unusual for reports from "the" radar set to be passed direct to the bridge even in large ships, though later it became usual for these to be handled through the Tactical and Aircraft Plots.

3. With the increase in numbers of radar sets fitted and their increased "vision," it was realised that the Tactical and Aircraft Plots had become entirely inadequate and needed a drastic increase in space, internal communications, and personnel if efficient use was to be made of even a portion of the information available from own and other ships' radar. In addition there has been a considerable increase in Y information including D/F which, with all other intelligence, needs to be related to that from radar.

4. This was the inception of the Action Information Organisation. Its function is to collect information from all available sources (radar being one of the largest contributors), relate and "filter" the information, and serve it up to the Command in a clear form. In fact the Command should receive the "answer" without having to worry particularly how the answer was obtained.

5. It follows, therefore, that the control of own ship's radar must be exercised from the Action Information Centre (A.I.C.), and this includes orders for switching on and off, sweeping rates and sectors, and the use of long or short pulse length. From this follows the fact that the Officers in charge of the Operations Room and Aircraft Direction Room and their deputies must have a firm grasp of the capabilities and limitations of radar (*Chapter I to V*) and the correct orders to give (*Chapter XXIII*).

RADAR DISPLAYS

6. With the introduction of continuously rotating radar aerials it became practicable and profitable to locate remote radar displays of the P.P.I. type actually in the A.I.C. It should be made clear, however, that the responsibility for warning, *i.e.* observing and reporting echoes, still lies with the operator in the Radar Display Room or warning radar office concerned. Dangerous confusion is likely to arise if the plotter or other individual at a remote position temporarily assumes this function, only to have to drop it a few minutes later on account of plotting or other duties. Further, the remote position will frequently be turning down the P.P.I. input in order to get better discrimination, and this will reduce warning; whereas the P.P.I. in the radar office can and should be kept permanently in the best condition for maximum warning.

7. In fact, the object of fitting remote radar display is :—

(a) As a convenience in order to see at a glance the *present* general surface (or air) situation, particularly if the plot has become confused.

(b) In order to study in detail a particular part of the radar view, *e.g.* the escort, a convoy, the coast, or an enemy unit.

(c) Where controlled interception is being carried out by means of radar, to enable absolutely up-to-date information of a few selected targets to be plotted direct, so cutting out all time lag. The most usual case at present is fighter interception of enemy bombers, for which the Skiatron is provided. The Skiatron has a surface larger than a P.P.I., and on which it is possible to plot.

8. Nevertheless occasions may arise, particularly when the density of targets is high, when it may be useful or even necessary for selected targets to be "told" direct from the remote display on to the local operations plot in the Operations Room. On such occasions care must be taken to define the precise responsibilities of the radar office watchkeeper and the local "teller."

9. In order to get full value, it is clearly necessary for the Operations Room Officer, F.D.O. and ratings concerned to know how to adjust a P.P.I. Attention is therefore particularly invited to the few simple rules for doing this, given in *Chapter II*. If the P.P.I. is not properly adjusted to the requirements of the moment it will give a confused picture and/or small targets will not appear at all.

10. Two important limitations of remote radar display must be pointed out :—

(a) It may give a false impression of security. In fact all that is shown is *what own radar can detect* (and it will not even show that if the P.P.I. is not properly adjusted). There may well be other objects there, and this may indeed be known to the A.I.C. from intelligence or other ships' radar.

(b) It only gives the *present* position of echoes, and gives no clue as to their past movement and therefore their likely future movement. Only the plot can show this.

It is on account of the above limitations that the fitting of a P.P.I. on the bridge is not countenanced except in cases where it is impossible to fit an efficient viewing device to the Bridge Plotting Room.

11. It is usual to arrange that a P.P.I. or Skiatron can be worked off more than one radar set. This is primarily as an insurance against breakdown, and the P.P.I. should normally be kept switched to the proper set according to the type of information usually required (surface, low aircraft, or high aircraft). To change over sets of the same basic type, such as types 277 and 293, the procedure is to stop both with the aerials pointing in the same direction, *e.g.* forward, and make the change-over switch. An auto-aligning device will later be fitted, which will dispense with the necessity of stopping aerials.

12. With R.N. sets of dissimilar basic type, such as types 277 and 281B, the change-over is more complicated and takes up to half an hour. With a mixed bag of R.N. and U.S. sets, which use different methods of internal transmission, change-over is not possible except in special cases.

COMPARTMENTS OF THE A.I.C.

13. The compartments of the A.I.C. comprise the Operations Room, Aircraft Direction Room, Target Indication Room, and Radar Display Room (with Height Filtering Position). These are the places where information is collected, collated and then passed to the Command through the medium of the Bridge Plotting Room (*para. 20*). The following description includes only the radar aspect, but it should be remembered that they have many other sources of information as well. For convenience the Bridge and Air Defence Position are also mentioned. These are the recipients of filtered information, for whose benefit the Action Information Organisation functions.

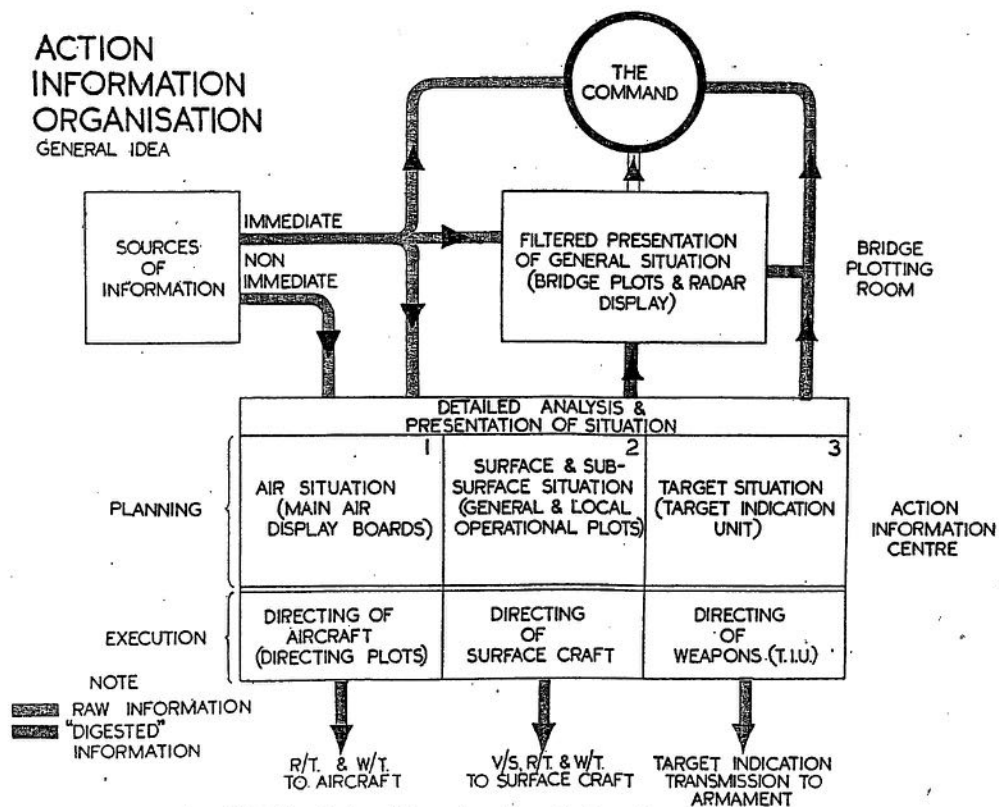


FIG. 25. Action Information Organisation—General Idea.

14. The general layout of the Action Information Organisation is shown in *Fig. 25*, and the radar aspect is illustrated in *Figs. 26 (a), (b) and (c)*, which show typical arrangements in a Battleship, Fleet Carrier, and Fleet Destroyer. It must be understood, however, that the actual layout of A.I.C. Compartments and displays varies considerably, and depends on space and equipment available. Also on the latest thought, the organisation still being in its youth.

Operations Room

15. This replaces the old "Tactical Plot" and as far as radar is concerned deals primarily with the surface situation and contains the Local and General Operational Plots (L.O.P. and G.O.P.). The P.P.I. is normally operated from the WS set (type 277), but is switched to the WC set (type 293) if type 277 is in use for heightfinding as may often be the case in carriers or other ships directing fighters.

16. In larger vessels, and where space permits, it is intended to fit an auto-radar plot, which is an A.R.L. table combined with a Skiatron. The primary object of this is to speed up radar-plotting by providing a plotting surface which will give a geographical position on the actual radar display.

17. Enemy reports based on radar will be originated from the operations room.

Aircraft Direction Room (A.D.R.)

18. This is a development of the old "Aircraft Plot." It contains:—

(a) *The main aircraft display plot (M.A.D.P.).* This is fed verbally from all sources of own ship's warning radar (e.g. WA set or sets and WS set) capable of detecting aircraft, and also receives by V/S, W/T or R/T radar reports of aircraft from other ships in company. The plot also receives heights from the Height Filtering Position. From the Plot the A.D.R. originates internal Air warnings. Subject to the orders in force, the A.D.R. also originates air warnings to the fleet, and signals details of own ships' radar detections (see Chapter XIX).

(b) *Interceptor Plots.* For the purpose of carrying out actual interceptions of enemy aircraft one or more Skiatrons are provided, and one of these may eventually be an auto-radar plot (para. 16) in order to introduce the geographical element. The Skiatron is normally operated from WA type 281B, but the alternative WS type 277 may be used if the interest is expected to be principally in low aircraft, or if operating near the land when the type 281B picture is likely to be very confused. In conjunction with the Interceptor Plot Skiatrons are fitted one or more P.P.I.s which can be operated from WA type 281B, WS type 277, or in certain cases WC type 293. The P.P.I. will normally be operated from type 277 if the Skiatron is on type 281B, and vice versa, thus filling the gap in coverage. The object of Switching to type 293, where fitted, is to display high aircraft at close range, such as overhead shadows or own fighters. Type 79/B cannot operate on P.P.I. or Skiatron because of its large beam width.

19. It must be emphasised that the A.D.R. is responsible for knowing the air situation as a whole, and for passing information to the Bridge, Bridge Plotting Room, Air Defence Position and Target Indication Room (and also to the Fleet if ordered). Although the F.D.O. is in charge of the A.D.R., its functions are definitely not limited to fighter direction.

Bridge Plotting Room (B.P.R.)

20. It has been shown that the A.I.C. collects and sorts all information flowing into the ship, and that this information is passed to the B.P.R. for the benefit of the Command. The B.P.R. contains a G.O.P. and an L.O.P. showing the surface situation, and a filtered air plot showing the air situation. It is these plots which will be studied by the Command, and from the information shown on them that decisions will be made and the battle fought. From here also surface targets will be selected and indicated to the armament by the P.C.O. when not acting on visual information.

21. In Flagships the B.P.R. is required to be immediately accessible from the Admiral's Bridge. It is, in fact, sited on the same level and immediately abaft the latter. If the Admiral does not elect to remain in the bridge plot, he will at least have some of the senior officers of his staff stationed there to keep him informed of the situation. To enable the Captain, on the upper bridge, to study the plot and its associated P.P.I. without leaving his action station, a viewing device is provided from the compass platform to the B.P.R. through which both the plot and the P.P.I. may be seen.

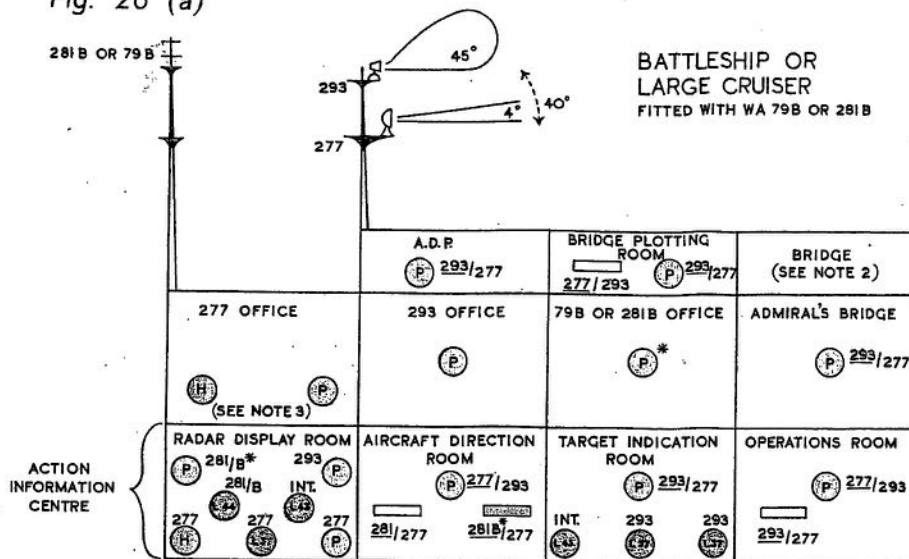
Target Indication Room

22. The function of the Target Indication Room is implied by its name, and the details are explained in Chapter XII. The T.I.R. may be a separate compartment, or may form part of the A.D.R. If the former, it may not be possible for the Target Indicating Officer readily to get a sight of the M.A.D.P., in which case he will have a hand plot kept by a plotter on a telling line from the M.A.D.P. to exhibit the essential filtered tracks and information to him. Radar display is from the Target Indication set WC type 293 with alternative from WS type 277.

P.C.O. and A.D.P.

23. The A.D.O. is provided with P.P.I. from type 293 (or type 277) if space permits. The P.C.O. is similarly provided if he cannot easily use the viewing device to the B.P.R.

Fig. 26 (a)



*SKIATRON AND P.R.I.'S OMITTED IF 79B FITTED

Fig. 26 (b)

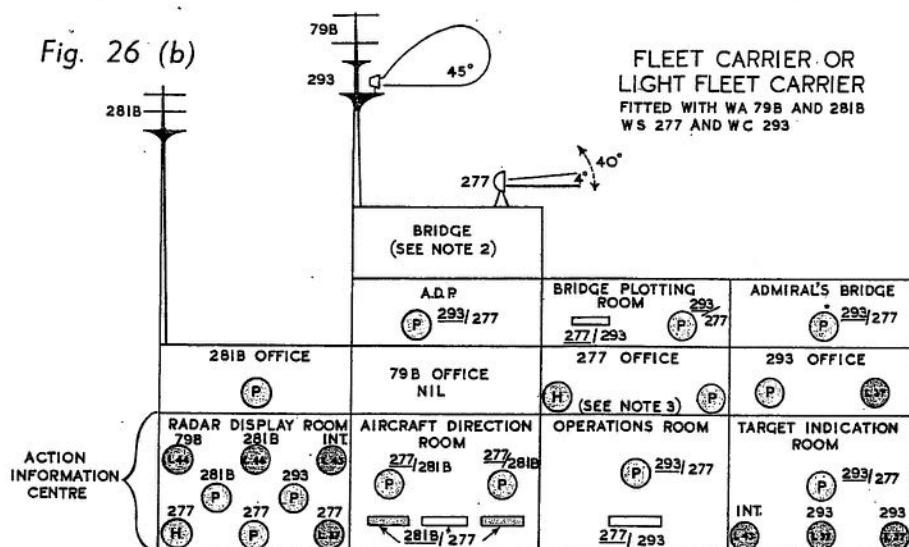
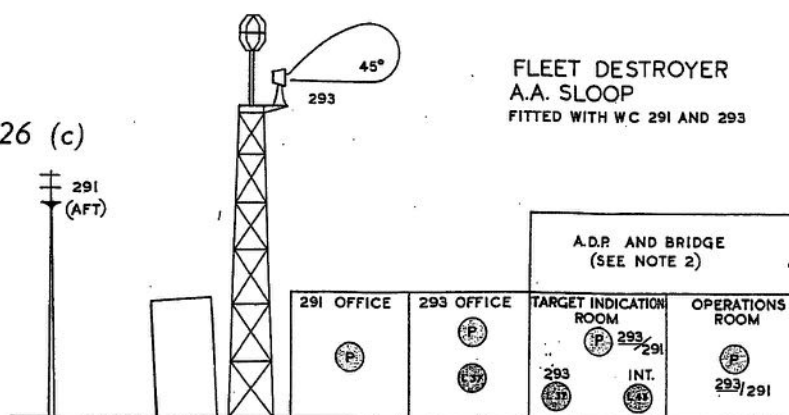


Fig. 26 (c)



TYPICAL RADAR DISPLAY REQUIREMENTS IN THE ACTION INFORMATION CENTRE

KEY:- (P) P.R.I. (H) H.R.I. (S) SECTOR DISPLAY (SK) SKIATRON (AR) AUTO RADAR PLOT

NOTES:- 1. WHEN TWO SETS WORK THE SAME INSTRUMENT ALTERNATIVELY, THE NORMAL SET IS STATED FIRST AND UNDERLINED THUS 277/293

2. A SEPARATE P.R.I. IS REQUIRED BY THE P.C.O. IN ALL CASES WHERE HE HAS NOT GOT READY ACCESS TO THE COMMAND'S P.R.I., WHERE AN EFFICIENT VIEWING DEVICE TO THE B.P.R. CANNOT BE FITTED, A P.R.I. WILL BE REQUIRED ON THE COMPASS PLATFORM

3. WHEN REMOTE CONTROL OF TYPE 277 IS FITTED, 'A' DISPLAY ONLY WILL BE FITTED IN THE TYPE 277 OFFICE

Radar Display Room (R.D.R.)

24. The ultimate intention is to group together remote displays from all warning sets in a Radar Display Room near the Operations and Aircraft Direction Rooms, and to include the Height Filtering Position and a Central Interrogating Position in the R.D.R. In many ships, however, space at present precludes fitting the full requirements, and the H.F.P. may be sited separately, or the R.D.R. may contain only the displays necessary for an H.F.P.

25. It must be made clear that the function of the R.D.R. is *not* to control the radar. This must be done from the Operations and Aircraft Direction Rooms. See *paragraph 29*, below. The advantages of an R.D.R. are :—

(a) It provides a convenient central position in which the Radar Officer can supervise the technical performance of all warning sets.

(b) The Radar Officer can also supervise the working of the Height Filtering Organisation.

(c) The R.D.R. being accessible will be able to give immediate technical advice to the Operations and Aircraft Direction Rooms as to the best action to take in the event of breakdown or jamming of one or more sets, or if atmospheric interference or anomalous conditions are present.

26. The Height Filtering Position (H.F.P.) is explained more fully in *Chapter XI*. It receives all height information from WA, WS or special heightfinding sets, and provides the A.D.R. or T.I.R. with the best height estimation for any target. By centralising the information it is frequently possible to clear up ambiguity in height which might occur from the use of only one set, or two sets independently ; and it helps to avoid two targets being plotted when there is really only one.

27. The Central Interrogating Position is described in *Chapter XIV*.

Small Ships

28. The Action Information layout described above applies generally to large ships (in Aircraft Carriers the A.D.R. layout is obviously more extensive than in a battleship or cruiser). In small ships the layout is proportionally smaller. For example, in a Fleet Destroyer a combined chartroom and operations room is provided, with the T.I. Unit in the adjacent T.I.R. Since the A.I.C. is sited in the bridge structure, and a viewing device is fitted between Bridge and operations room, no B.P.R. is necessary.

CONTROL OF RADAR

29. The operations room, A.D.R. and T.I.R. are fed by radar information from the Surface Warning, Aircraft Warning, and Target Indication sets. It is clear, therefore, that they must directly control the operation of these sets, subject, of course, to any special orders from the Captain or the Senior Officer.

30. As a rule the sets fall naturally into the three categories WS, WA and WC (T.I.). Complications may arise however, *e.g.* :—

(a) The WS set is usually the best detector of low flying aircraft. It is possible that the Operations Room may wish to sweep a Sector by hand training to search for E-boats, or to obtain better bearing discrimination. This will react on all round low air cover.

(b) The A.D.R. or T.I.R. may wish to use WS type 277 for heightfinding, which means stopping its sweep.

(c) Consequently the T.I. set, WC type 293, may temporarily assume a tactical function (in Carriers and Fleet Destroyers it is the normal tactical set). Here again there are two conflicting requirements, as for surface warning a slower sweep rate and longer pulse length are usually desirable, while target indication demands the opposite in order to get better discrimination and compete with a high rate of change of bearing.

31. It is clear that a high degree of co-operation between the Operations Room, A.D.R. and T.I.R. is necessary, and a suitable organisation must be worked out in each ship, conflicting interests being referred to the Captain if necessary.

CHAPTER VII

SURFACE WARNING AND THE TACTICAL USE OF RADAR

1. The ability of radar to "see in the dark" must clearly have a profound effect on tactics. It is interesting to speculate how the battle of Jutland would have finished had we had even moderate radar in those days. Now that surface warning radar can obtain horizon range (and sometimes see beyond the horizon), and highly effective radar has been developed for "blind" gunnery and torpedo control, we are approaching the time when night action may be sought and fought at ranges equal to those by day.

2. As British and American night actions in this war have already shown, the dice is heavily loaded in favour of the side with better radar, always provided it is being used to best advantage. However, it is perhaps not unfair to say that the Tactical use of radar (except in the specific case of A/S) has up to date received less attention than some of its other applications, such as gunnery and fighter direction. The purpose of this chapter is to indicate how to get maximum benefit from surface radar: as usual this also demands an appreciation of what radar will *not* do.

3. In general it may be stated that radar has not affected any of the *principles* of tactics. It has, however, affected the method of execution considerably.

CAPABILITIES AND LIMITATIONS OF RADAR USED FOR TACTICS

4. The advantage of radar is self evident, and the capabilities of the various types have been described in *Chapter III*. The tactical uses to which radar may be put are described later in the chapter. In the event (now unlikely, but always possible) of the enemy having no radar, complete surprise may be achieved.

5. The limitations can be summarised as follows:—

- (a) Unless P.P.I. is fitted, radar can only see in one direction at a time.
- (b) Although radar gives the target's present position it does not immediately give its course and speed. These have to be obtained by plotting successive observations, and are, therefore, never completely up-to-date.
- (c) Fundamentally radar cannot distinguish between friend, foe or neutral, but has to be supplemented by a radar recognition system, or intelligence (*see para. 6*).
- (d) Discrimination between several targets, or between targets and land, is not so good as that of the human eye by day, and radar when trained on one target casts a shadow around it in which a second target will not be detected.
- (e) Like other radio systems, radar is susceptible to radio counter-measures, and this may ultimately develop into a race like that between gun and armour.

RECOGNITION

6. To make possible recognition by radar methods all Allied warships and aircraft are, or should be, fitted with Interrogators and I.F.F.; some Allied merchant vessels may also be fitted with I.F.F. The I.F.F. system, which is fully described in *Chapter XIV*, should therefore theoretically overcome one of the fundamental limitations of radar by indicating which echoes are "friendly." In the latest modification of the set, type 253P, coding may also establish the identity of a particular ship or unit, while special codes are provided in all I.F.F. sets to indicate ships or aircraft in touch with enemy surface craft (code 4), or in distress (Distress code).

7. 100% certainty of recognition cannot, however, be provided by the radar recognition system, because:—

- (a) The I.F.F. (or interrogator) may be defective, or not switched on. (It is useful to remember that there is a signal meaning "Switch on I.F.F.").
- (b) The I.F.F. may become "saturated" if there are a lot of ships and therefore interrogators in the vicinity. In fact during the 1944 invasion operations it was necessary to "ration" the use of I.F.F. for this reason.
- (c) The enemy might imitate our I.F.F.

8. Consequently I.F.F. must be considered only as a quick means of establishing probable identity, and before a new echo is classified in the Operations Room as "Friendly," "Unidentified," or "Hostile," other evidence must be weighed, *e.g.*:—

- (a) Intelligence, including knowledge of the previous and likely movements of own and enemy ships.
- (b) D/F bearings of enemy or own W/T or R/T.
- (c) Bearings of other friendly radar transmissions.
- (d) The likelihood of merchant ships or fishing vessels being in the vicinity.

9. Some estimate of the *size* of a new radar echo may be obtained from the rate of increase in echo height, as described in *Chapter V*. A quicker estimate can be obtained from the range of first detection (assuming a constant sweep is in progress), but this method is very apt to be misleading under conditions of anomalous propagation which are common in hot climates.

DISCRIMINATION AND RADAR SHADOW AREAS

10. The following remarks may seem rather technical, but it is necessary to understand them as they have an important bearing on tactics.

Range discrimination

11. Owing to the pulse length an echo is not a sharp peak but extends on the trace of the "A" display some distance beyond the leading edge of the echo. This distance varies in warning sets between 150 and 400 yards, according to whether short or long pulse length is in use. Within this distance it is for practical purposes not possible to distinguish the echo from a second target which is on the same bearing or nearly the same bearing, viz. within the bearing discrimination of the set. In these circumstances it will only be practicable to see the second target when the range difference increases sufficiently.

12. Alternatively, when using "A" display, a change from long to short pulse length may separate the echoes, *i.e.* give better range discrimination, but this will have the effect of reducing the detecting capability of the set.

13. When using P.P.I. display the range discrimination is dictated by the size of the spot of light which paints the echoes. Except on the shortest range scale the spot size is always greater than the long pulse length of a WS set, and on normal range scales switching from long to short pulse length will not therefore improve range discrimination.

14. The use of the shortest range scale, either on P.P.I. or "A" display, has the effect of improving range discrimination since the echoes are not so crowded together.

Bearing discrimination

15. Owing to the width of the radar beam it is impracticable to distinguish two targets which are on the same or nearly the same bearing if they are also at the same or nearly the same range, viz. within the range discrimination distance. In these circumstances the two targets will not appear as separate echoes unless they open out till their bearing differs by an angle which is called the "bearing discrimination" of the set.

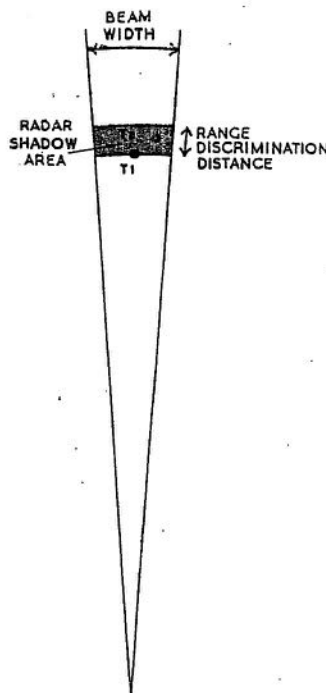


Fig. 27—Cause of radar shadow area. The echo from target T2 cannot be seen since it is in the shadow area caused by target T1.

Radar shadow area

16. It will therefore be seen that whilst detecting a target the radar effectively throws a "radar shadow area" around it (or to be more precise beyond and each side of it) which will obscure any other targets within the area. This is illustrated in *Fig. 27*. Similarly when close to the land (and especially if it is high land) the radar beam as it sweeps will throw a shadow along the coast and thus cause a "radar shadow area" near the shore within which targets cannot be detected. This is illustrated in *Fig. 28*. The limits of the shadow area are obtained by joining the points which are at the same range as each part of the land detected, but set out by an angle equal to the bearing discrimination. For practical purposes when using P.P.I. this angle can be taken as the width of the horizontal coverage diagram at normal working range (loosely called the "beam width"), and a simple protractor can therefore be made and used for quickly tracing the shadow area. The difference between *Figs. 28 (a)* and *(b)* should be noted. When the land is viewed obliquely a much larger shadow area is obtained than when viewed at right angles, since the effect of the beam width is then greater.

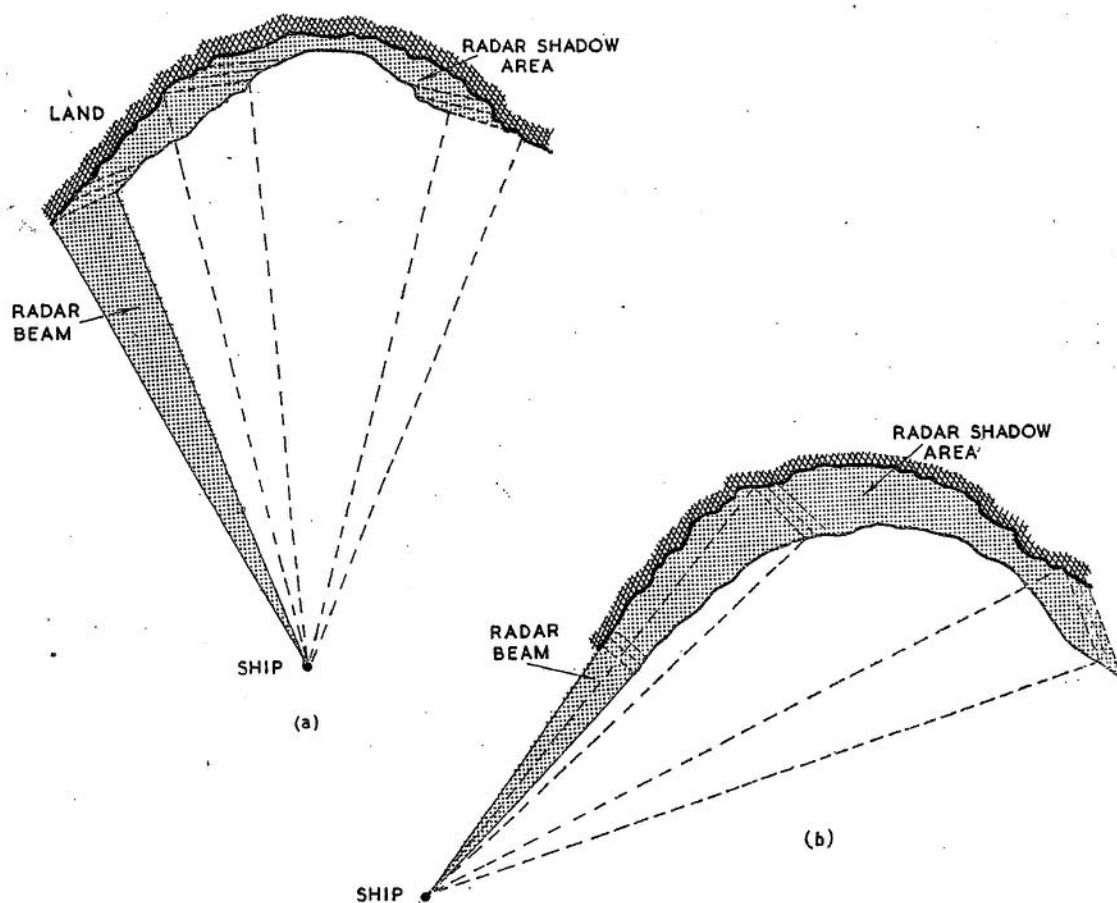


Fig. 28—Showing the radar shadow area thrown around a coast line as the radar beam sweeps past. In (a) the land is being viewed approximately at right angles, in (b) it is being viewed obliquely; it will be seen that the shadow area is considerably larger in the latter case. The shadow area as seen from any particular position can be constructed by joining points which are set out from the land by the width of the horizontal coverage diagram, as shown by the pecked lines in the above figures.

Difference between bearing discrimination using P.P.I. and "A" Display

17. It is necessary to expand a little on the meaning and effect of bearing discrimination.

18. **Using P.P.I.** Continuous rotation using P.P.I. display is the normal method of operating warning sets. The P.P.I. is fitted with a "limiter," the effect of which is to accept all echoes that are of sufficient strength (usually "twice noise"), but to paint them with equal brightness on the P.P.I.

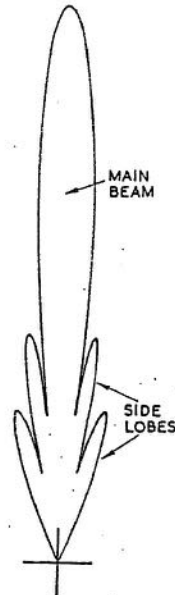


Fig. 29—Horizontal Coverage diagram of a typical WS set (type 277). The outer line encloses the area within which a target of given size can be detected when the radar aerial is pointing in a given direction.

19. Fig. 29 shows the horizontal coverage diagram of a typical WS set. The edge of the diagram represents the positions in which a target of given size will just be detected, *i.e.* give a "twice noise" echo, when the radar aerial is pointing in a given direction. Inside the area of the diagram the echo will be stronger, and it will be strongest on the centre line, but owing to the "limiter" this difference will not be apparent on the P.P.I.; the target will be shown at equal brightness on the P.P.I. if it is anywhere inside the coverage diagram, and will not be shown at all if it lies outside it.

20. The effect of this on P.P.I. bearing discrimination is shown in Fig. 30. All targets are assumed to be the same size, and AA', BB', etc., are separated by the same angle of bearing. The length of the echo that each pair of targets paints on the P.P.I. is shown, and these pairs of echoes are all of equal brightness (and thickness). It is clear that at any range the bearing discrimination on P.P.I. is equal to the width of the horizontal coverage diagram at that range.

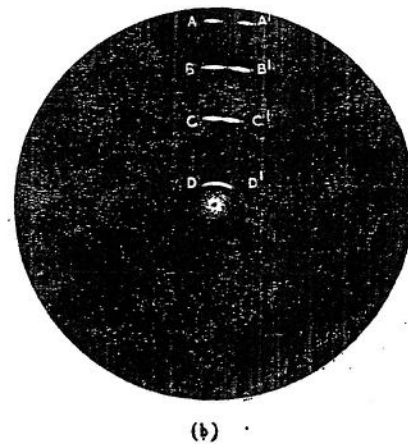
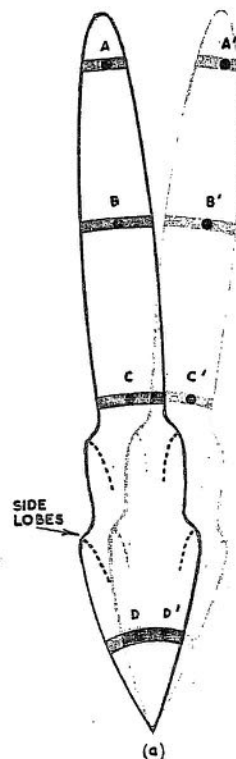


Fig. 30—Effect on bearing discrimination of width of horizontal coverage diagram at different ranges, when using P.P.I. display, vide paragraphs: 20–22. The coverage diagrams are for a typical WS set and the targets differ by ten degrees of bearing.

21. It will also be seen from *Fig. 30* that the bearing discrimination on P.P.I. varies with range. At extreme range, where the coverage diagram is narrow, discrimination is best. Within the limits of normal working range the width of echoes of targets of equal size is roughly constant. At close ranges the effect of side echoes is to make discrimination poor, and in fact the echoes from CC' and DD' merge into one another and no discrimination on P.P.I. is possible.

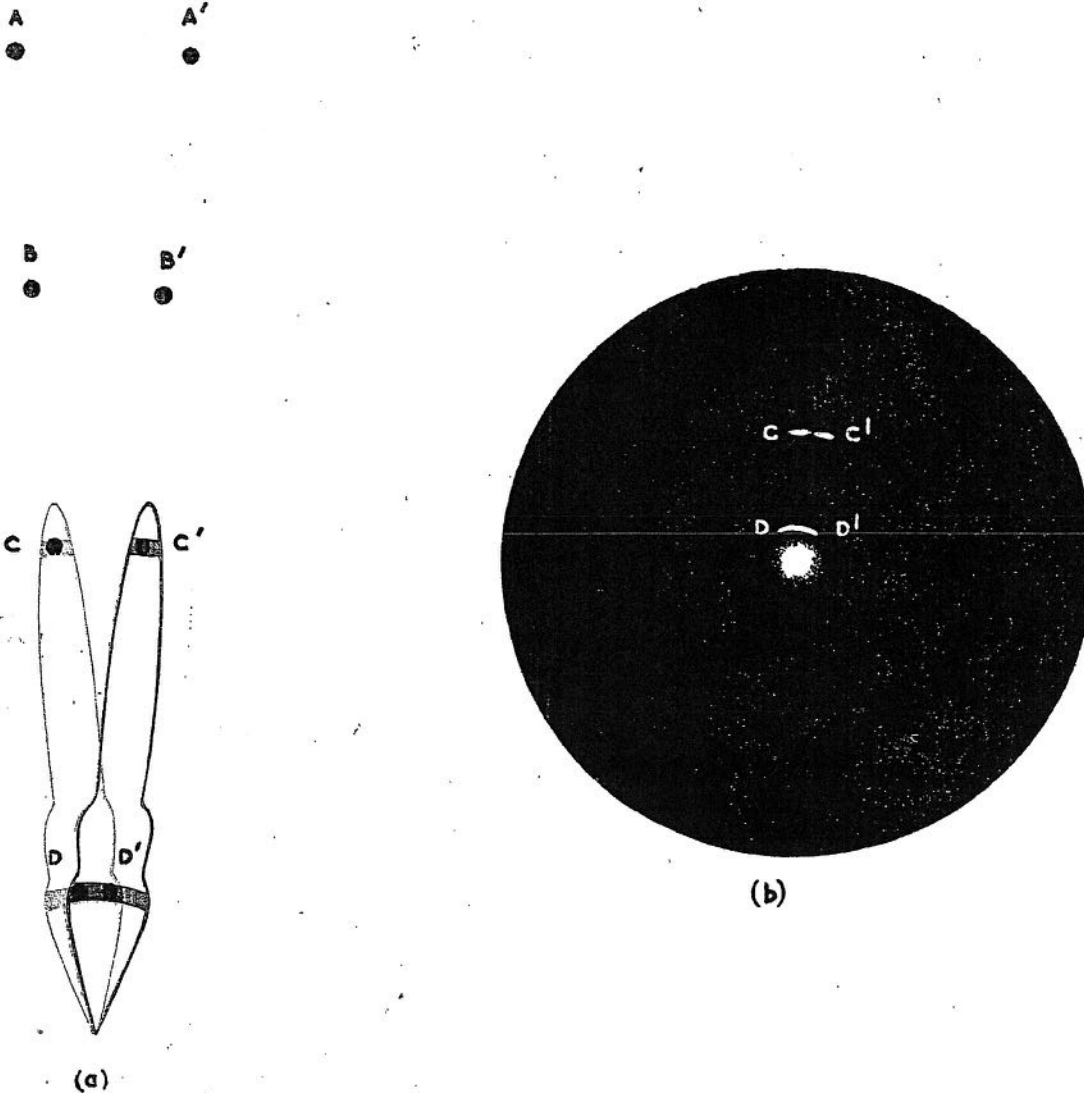


Fig. 31—This figure should be compared to *Fig. 30*, and shows the effect on bearing discrimination of reducing the P.P.I. input and thus contracting the horizontal coverage diagram. As a result, the bearing discrimination is improved, e.g. CC' can now be distinguished separately on P.P.I., but detection of longer range targets such as AA' and BB' has been lost. DD' still appear as one echo because of the very short range and the effect of side echoes.

22. Certain qualifications must, however, be made :—

(a) Reducing the "Input" has the effect of contracting the size of the coverage diagram, as shown in *Fig. 31*, which should be compared to *Fig. 30*. The result is better discrimination at the expense of maximum range.

(b) Different sized targets complicate the situation. Clearly a battleship will give a "twice noise" echo over a much larger area than a U-boat, and the coverage diagram for the former is therefore greater. Consequently bearing discrimination is worse for large targets, and is worst when detecting high land.

(c) Although bearing discrimination is not possible between targets such as CC' in *Fig. 30*, the exceptional width of the combined echoes should give rise to a suspicion that there are two targets, and it may be possible to confirm this by turning down the P.P.I. "Input" or reverting to "A" display. The same sort of reasoning applies to range discrimination; an exceptionally broad echo should lead the operator to suspect that there is more than one target; and the use of "A" display, switching, if necessary, temporarily to short pulse, may confirm this.

23. **Use of "A" Display.** The "A" display has no "limiter" and relatively good bearing discrimination can be obtained by training the aerial slowly and observing the rise and fall in the heights of echoes from targets at or near the same range. Thus, referring to *Fig. 32*, when the aerial is pointing in a direction 000° , target "A" will give a maximum echo. "B" will also give a weak echo (of "twice noise") though it will not be visible because it will be swamped by "A." However, by training only half the beam width, namely to 004° in this case, the position will be reversed; and by training to and fro it will be apparent that there are two echoes.

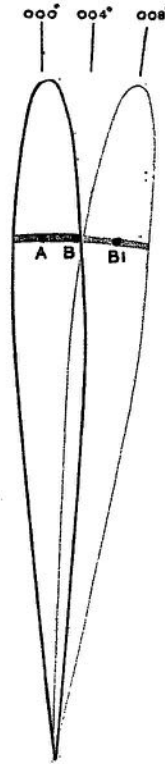


Fig. 32—Diagram showing how better bearing discrimination is obtained with "A" display than with P.P.I. (See paragraphs 23-26.) The coverage diagrams are for WS type 277.

24. Compare the difference with P.P.I. "A" and "B" would each have painted echoes 8° wide and of constant brightness (owing to the effect of limiter), and it would not be till "B" moved to "B1" that it would be possible to separate it from "A," i.e. that a gap would appear between the two echoes on P.P.I.

25. Bearing discrimination on "A" display is therefore about twice as good as on P.P.I., and is approximately equal to half the beam width. Further, except at extreme range the bearing discrimination on "A" display is a constant angle and independent of the range, since it depends on ratios and not strengths of echoes.

26. It will therefore be apparent that when the best discrimination is required it will be necessary to use "A" display in order to separate and count targets which are close together. This will usually mean reverting to hand training and temporarily surrendering all round sweep and P.P.I. display.

P.P.I. versus "A" DISPLAY

27. The following is a summary of the pro's and con's of P.P.I. and "A" display, based on the above remarks and those in *Chapters II* and *V*.

P.P.I.

28. (a) P.P.I. gives a continuous display of the present position of all targets within radar range.

(b) P.P.I. enables a larger number of targets to be "told" (*i.e.* reported) or watched simultaneously because the radar aerial does not have to be stopped to measure bearing.

(c) Because the radar sweeps continuously there is less chance of missing a fast closing target; reliability of detection is therefore greater.

(d) On P.P.I. it is much easier to follow moving targets amongst standing echoes, such as land echoes and wave clutter, and side echoes can be recognised more quickly because of their symmetrical position relative to the main echo.

On the other hand :—

(a) Discrimination is not so good as on "A" display. Bearing discrimination may be improved by turning down the input, remembering that warning is thereby reduced.

(b) Targets cannot be followed into the ground wave.

"A" Display

29. (a) Bearing Accuracy at close range is better than on P.P.I., where there is a very wide echo to bisect.

(b) Ranging accuracy is better (though in some sets accuracy of the "A" display can also be achieved without stopping spinning by means of a Sector Display).

(c) Discrimination is better. Bearing discrimination is normally about twice as good as on P.P.I., and is independent of range. Owing to the effect of P.P.I. spot size, range discrimination on "A" display is normally better and can be further improved by using short pulse.

(d) Targets can be followed into the ground wave by means of "Watson effect."

On the other hand :—

(e) Only one direction can be viewed at a time, which slows up reporting and reduces the reliability of all round cover.

30. It is clear that although P.P.I. is obviously the most convenient form of display for general warning and tactical purposes, the "A" display has by no means lost its value, and the two must be used in conjunction.

WEAPON TACTICS

31. The radar considerations which primarily affect *gunnery tactics* are :—

(a) The range at which full radar blind fire can be carried out.

(b) The effect of Radar Shadow Areas.

Radar blind fire

32. Nowadays it is as important to know the range at which the armament can effectively use radar blind fire as it is to know the maximum and optimum fighting ranges by day.

33. With GS type 284 (or GA type 285 in a destroyer) the effective range in blind fire is limited by the maximum splash spotting range. This is about 20,000 yards for a battleship and 8,000 yards for a destroyer under fair weather conditions, but may be much reduced in bad weather, and the effect of yaw on bearing accuracy will then also be felt. Tactically it is important for each ship to know the effect of bad weather on her ability to fire blind; no precise figures can be given here because no conclusive reports have been received.

34. With GS type 274 (or GA type 275 in a destroyer) the splash spotting range is very much greater (over 30,000 yds. for 14-inch shell), and the effective range of the gun itself may prove to be the limiting factor for blind fire.

Radar shadow area

35. The "Shadow Area" cast by radar around a target or by land can be put to good use tactically.

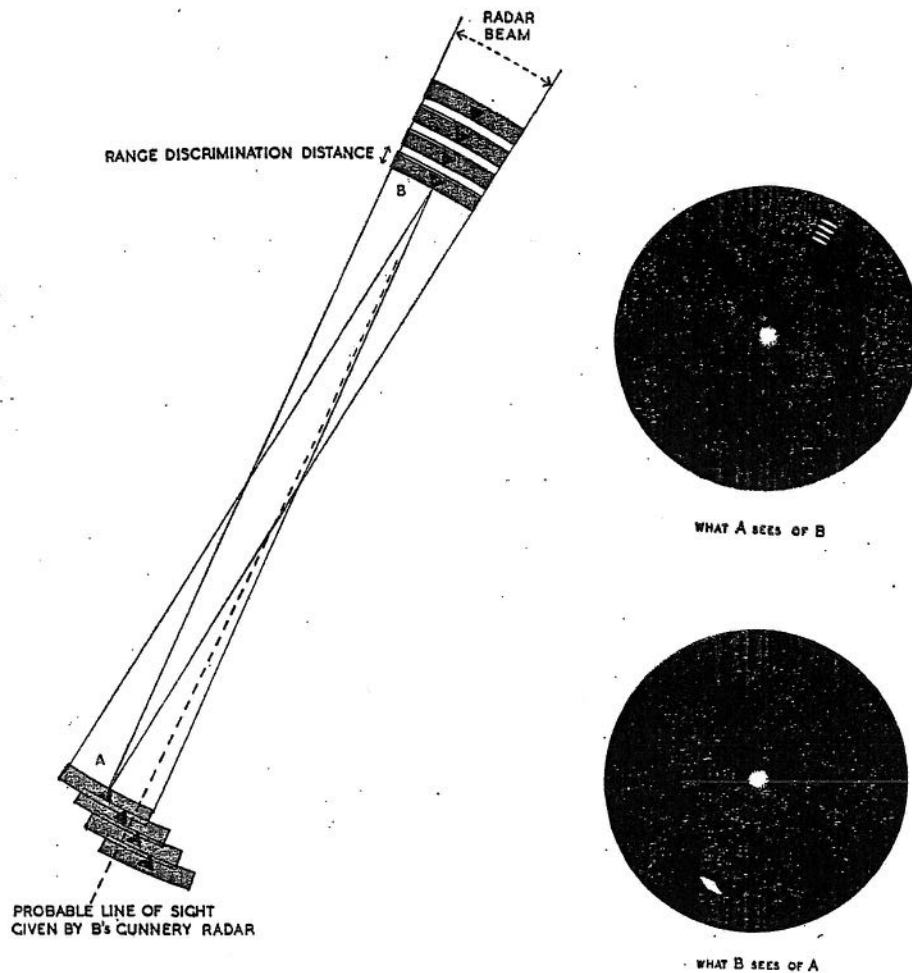


Fig. 33—Radar shadow areas associated with two opposing fleets, vide para. 36. The above diagram assumes that each side has similar radar.

36. Fig. 33 shows two opposing fleets A and B which are approaching in quarter-line and line-ahead respectively. The radar shadow areas as obtained from the leaders' radar are shown. It will be seen that A can readily distinguish that there are four targets and could fire blind by radar at each. On the other hand, B will not be able to distinguish the separate ships in fleet A (particularly if P.P.I. is used and no check is made with "A" display, and indeed may not realise that there is more than one target at all. In any case, there is a strong probability that radar blind fire will be directed at the centre point of the unit (and therefore not at any one of the four ships) owing to the limitations of beam-switching as described in Chapter XII.

37. Under night or low visibility conditions the moral is obviously to keep on a line of bearing as nearly as possible at right angles to the enemy, and as close together as practicable; to neglect this will invite the arrival of well directed fire.

38. The subject is discussed more fully in Chapter 4 of C.B. 4112 (1), which should be studied, and which gives detailed guidance to the optimum distances between ships and their line of bearing. It must be remembered, however, that in the absence of exact knowledge of enemy radar it is impossible to be precise. It is also possible that several targets close together may be picked up at a greater range than would be each individually.

39. The radar shadow area can also be put to use when operating near land or among islands, either for evasion or to achieve surprise. Indeed, it might be turned to powerful advantage by small ships lying in wait for the enemy, and this subject appears to warrant further investigation at sea. In general, the closer to the land the better chance will there be of escaping enemy detection. It is not possible to be precise owing to the greatly differing reflectivity of the coast, which depends mainly on its height, but it is clear from *Fig. 28* that it is best to keep inside bays and avoid lying off headlands.

40. Conversely, as explained in *para. 16*, if the object is to detect an enemy lurking near a coastline or emerging from a harbour, the coast should be approached at right angles and not obliquely.

Evading detection

41. The desirability of evading detection by enemy radar, in order to achieve surprise, may also arise when small ships are preparing to develop a **synchronised torpedo attack**. Unless the shadow of land can be made use of, it is problematic whether detection can be avoided unless the enemy radar is distinctly inferior. If equally efficient radar is fitted, the probability is that the greater height of the enemy's radar will outweigh the effect of smaller size of the would-be firing ship. For example, type 271/3 ranges are Battleship v. Destroyer 36,000 yds. and Destroyer v. Battleship 26,000 yds., and the defensive properties of radar win in this case. If, however, the enemy radar is inferior, as we hope it is, it will be advantageous for our ships to keep as much head on (or stern on) to the target as possible, since this reduces the reflecting area and therefore their range of detection by the enemy.

RECONNAISSANCE, SEARCH AND PATROL

42. The main effect of radar on reconnaissance, search and patrol by *ships* is that, except for the limitations of recognition, it enables an area to be covered as effectively by night as by day. All that is in fact necessary is to substitute "Radar reliable range" for "visibility" in the design, "reliable range" referring, of course, to the size of target which it is required to detect.

43. Thus the necessity for "retiring in the dark" should no longer arise, nor should the necessity for units closing in by day when the visibility drops.

44. Alternatively, if the area to be searched is a limited one, *e.g.* a channel, the extension to vision given by radar at night may enable the number of units to be reduced, or their concentration increased with tactical advantage. The same applies to night screens.

45. It must be remembered, however, when designing searches or screens to take, the fullest advantage of radar, that it will be necessary to use W/T or R/T to report detections and perhaps to co-ordinate movements. The range of the inter-communication set and any limitations on its use must therefore be taken into account when deciding on the distance apart of units.

46. An interesting example of the use of radar was that of H.M.S. "Suffolk" when patrolling to intercept the "Bismarck" in 1941. One side of the Denmark Straits was covered in fog, and "Suffolk" therefore correctly kept near the edge of the fog bank and used vision to cover one side and radar to cover the other. In fact "Bismarck" was sighted visually.

47. *Aircraft* are also fitted with radar (ASV) which considerably increases the reliability of air reconnaissance by day and makes night reconnaissance a practicable proposition. See *Chapter XVIII* for the capabilities of ASV and its limitations.

SHADOWING

48. The technique of shadowing has been altered by radar. Once the target has been identified there is now no necessity at night or in low visibility to close to sighting distance at intervals (indeed with the advent of blind fire this would now be an exceedingly unhealthy proceeding), and the danger and uncertainty of maintaining contact at dusk and dawn do not now exist. Instead, the shadower can remain at a respectful distance, outside the range of effective blind fire, and still obtain all the information required. It is unlikely that the shadower will herself escape detection, for the reasons given in *para. 41*, unless she is a very small ship.

49. The following guidance refers to the radar aspect only. There may well be other tactical considerations, as referred to in the Fighting Instructions.

Range at which to shadow.

50. Any range between effective blind fire range (from the enemy) and reliable detection range (of the enemy) is suitable. It is probably best to keep just inside reliable detection range. This will provide a margin should the enemy make a sudden alteration of course and speed, and enable him to be held while his own ship regains position. During "Suffolk's" historic shadowing of "Bismarck" the conditions were far from easy as the visibility varied a lot and the range of the old radar was comparatively poor, so that shadowing had to be carried out at extreme radar range. "Bismarck" eventually threw off her shadower by increasing speed till she was just outside radar range and then making a drastic alteration of course.

Bearing from which to shadow

51. The beam position is slightly better for quickly detecting an alteration of course, and an ahead or astern position for quickly detecting an alteration in speed. If, however, there is any chance of coming within gun range, a much more important factor is that enemy gun fire is likely to be less accurate for line than for range, particularly when firing blind. In general, therefore, it is best to shadow from astern (or ahead if the radar has a clear arc aft), and this will also increase the remote possibility of escaping detection by the enemy. If there are two shadowers, positions fine on the quarter (or bow) should be chosen. From a radar point of view more than two shadowers are unnecessary, and indeed may confuse the situation. Other ships should therefore keep clear or form up with the shadowers.

CONTROLLED SURFACE INTERCEPTION

52. A tactical use of radar which has come into prominence is the technique of a ship directing smaller vessels on to a target which has not yet been detected by the smaller ships' radar. This technique has been in use for a long time ashore, e.g. in the Dover Straits where M.T.B.s are directed on to enemy convoys, and has its counterpart in Fighter Direction using air warning sets.

53. The two particular uses of shipborne radar for this technique at present are :—

(a) For directing own patrolling M.G.B.s on to enemy E-boats. This was carried out successfully during the invasion operations using type 277 or 293 in a cruiser or frigate.

(b) For directing own destroyer screen on to U-boats. This was tried by a battleship in the Mediterranean.

54. The type 277 range from a Battleship or Cruiser against a U-boat or E-boat is of the order of 20–22,000 yds. Those from a destroyer (type 293) or M.G.B. (type 291) against a U-boat or E-boat are 10,000 and 3,500 yds. respectively. There is thus a considerable distance over which direction can usefully be given before the attacking vessels themselves locate the target. The object is to position them so that they can make their final approach (using their own radar) from the most advantageous position, e.g. down sea and from the dark quarter.

55. For controlled interception immediate communication direct from the operations room is required, and R/T using Plain Language is much to be preferred to W/T for the purpose. The bearing and distance of the target relative to the attacking force should be passed at intervals in addition to the vector courses to steer. When the attacking force have themselves detected the target, control should cease and the senior officer of the attacking force given a free hand and undisturbed use of the communication channel.

ANTI-SUBMARINE WARFARE TACTICS AND TORPEDO CONTROL

56. These are particular cases where radar is used for surface warning and tactical purposes, and are dealt with in separate *Chapters VIII* and *XIII* respectively.

57.–59.

CONTROL OF SURFACE WARNING RADAR

60. The WS set is the primary source of radar information for tactical purposes, and as explained in *Chapter VI*, control of this set is exercised from the Operations Room. If WS Type 277 is in use for height-finding, or if only WC Type 293 is fitted, the latter set becomes the primary tactical radar set. In the event of breakdown of both of these sets, arrangements must be made to provide surface cover from the GS set, a GA set, or WA set (if type 281/B). The gunnery sets give the better surface range but are less handy to use because they are fixed to a Director and can only sweep slowly.

When to use surface warning radar

61. Subject to the Radar Policy in force (*Chapter XIX*) surface warning radar should be used whenever the visibility is less than the maximum radar range of the largest type of target it is desired to detect, bearing in mind the need for occasional rest and maintenance routines.

62. Thus if the interest lies particularly in E-boats or U-boats there is no object in using radar on a fine day. If, however, the quarry is a raider, whose detection range might be 20 miles or so from a cruiser, there will be many days on which radar should be used. Normally the WS set is always used at night.

Instructions which must be given by the Operations Room

63. It is the responsibility of the Operations Room to give the radar office the following instructions and/or information :—

- (a) Orders to close up and to commence operating.
- * (b) Type of sweep—all round or sector.
- * (c) Rate of Sweep.
- * (d) Range scale to use.
- * (e) Pulse length to use.

* *Note.*—In the absence of orders, all round sweep at normal rate, medium range scale, and long pulse will always be used by a warning set.

- (f) Whether targets are to be interrogated automatically, or only by order from the Operations Room. (This arises because the Radar Policy for WS sets and Interrogators may not be the same.) In the absence of orders, interrogation will be carried out automatically.
- (g) The relative position of other ships in company, and any subsequent change of any consequence. This helps the operator to visualise the situation and helps to ensure that he will quickly appreciate the appearance of a new echo (*e.g.*, from a U-boat) at close range.
- (h) Subsequent orders to investigate, watch, hold, or disregard targets reported.

Type of sweep (all round or sector) and rate of sweep

64. With *new sets* (types 276/277/293 and SG) having spinning aerials and P.P.I. display all round sweep is normal, and little is gained by reverting to hand control and sector sweep. This should only be employed :—

- (a) If it is desired to search for small targets in a particular sector, *e.g.*, E-boats approaching up channel or down moon. Provided the sector is small enough this procedure may give a better chance of detecting the fluctuating echo of a small target at extreme range. The P.P.I. will paint down to a speed of about 1 r.p.m. and may still be useful while sector sweeping.
- (b) If it is necessary to obtain the best possible discrimination, *i.e.*, to separate and count targets.

65. If sector sweep is used it must be remembered that all round cover has been temporarily lost, unless this can be provided from an alternative such as the WC set (type 293).

66. Although in theory the rate of sweep of spinning aerials should be as fast as possible up to 15 r.p.m., in practice the best rate of sweep for warning purposes is generally found to be about half speed and for type 277 should be about 6 r.p.m. This is a compromise between going slow enough to avoid watchkeeping strain and going fast enough to get up-to-date information. In some sets, *e.g.*, type 268 and 970, the spinning rate is fixed. In WC type 293 two alternative speeds (15 and 7½ r.p.m.) are provided, and if this set is being used for warning as well as target indication the slower speed should normally be used when searching.

67. With *old sets* (types 271/2/3) the aerials are rotated by hand, and P.P.I. display may or may not be fitted. Normally an all round sweep should be used, but owing to the aerial stops this has to be done first clockwise and then anti-clockwise, which reduces the reliability of cover. Normally it pays to sweep as fast as possible, and the rate should be 360°/min. with P.P.I. and 180°/min. without P.P.I. In rough weather without P.P.I. the rate must be slower (90°/min.) when searching for U-Boats, to reduce the chance of the beam passing over the U-Boat while it is obscured by the swell.

68. Sector sweep may be necessary as in paragraph 64 (a). In addition, owing to the slow rate of sweep there is little object in sweeping aft of the beam if the ship's speed exceeds 24 knots.

69. Special rules for A/S sweeping are contained in *Chapter VIII*.

Range scale to use

70. The best watch-keeping range scale is that which just covers the maximum detection range of the type of target likely to be encountered. This is the 0-75,000 yds. scale with the WS sets and type 293. An occasional sweep on the 0-150,000 yds. scale should be made in case there is anomalous propagation, or to detect high land.

71. Exceptions to this rule are :—

- (a) When type 277 is used primarily as a low air cover set the 0-150,000 yds. scale should be used.
- (b) The 0-15,000 yds. scale is normally used by A/S escorts, with occasional sweeps on the 0-75,000 yds. scale.

72. The above rules refer to the scale used by the watchkeeping operator in the radar office. Where a remote P.P.I. is fitted any scale can be used, according to taste, without in any way affecting the watchkeeping. It will be common for example for the office to use 0-75,000 yds. (for warning) while the operations room use 0-15,000 yds. in order to obtain better discrimination and a more accurate picture of the local situation.

Orders to Investigate, Watch, Hold or Disregard

75. These terms are defined in *Table 3* and further explained in *Chapter XXIII*, and it is necessary for Control officers and ratings in the operations room to be absolutely sure of their meaning.

76. With sets whose aerials normally spin (types 277, 293 and SG) the order to "Investigate" a sector implies reverting to hand-training. With all sets the order to "Hold" means giving up sweeping and therefore P.P.I. display. In both cases all-round cover is lost.

77. The order to "watch," however, does not alter the type or rate of sweep, and therefore does not interfere with P.P.I. display, but the operator will make reports of the target more frequently. Unless told to disregard, all echoes are reported at regular intervals and it is therefore not necessary to order every target to be "watched": indeed there is a limit to the number of targets that the operator can efficiently "watch" if he is also to report all other echoes and search for new ones.

78.-79.

Action taken on obtaining a new echo

80. It is clearly not possible to lay down rules on the action to be taken by a ship on obtaining a new radar echo. From a radar aspect however the considerations are:—

- (a) To avoid running down the target before her movements can be ascertained and own ship brought to the necessary degree of readiness, and
- (b) To avoid losing touch.

81. The best plan is generally to alter course so as to bring the target on or slightly before the beam. This avoids a too rapidly closing rate and allows a plot to be established, and subsequent action decided.

82. Exceptions occur when:—

- (a) the initial detection is at short range and an E-Boat or U-Boat is suspected.
- (b) the target appears likely to menace other friendly ships not fitted with radar, e.g., a convoy.

In such cases an immediate turn away or towards may be called for.

Use of radar or countermeasures, etc., by the enemy

83. The Operations Room must be on their guard for radio countermeasures (*see Chapter XV*) which the enemy may use, especially if his radar is inferior to ours. He is unlikely to *jam* until our side opens fire because until that time it would only have the effect of disclosing his position. He might, however, lay a curtain of *window* from aircraft behind which he could approach and manoeuvre unseen by our radar. The presence of window must therefore be regarded with suspicion, though it is admittedly more likely to herald an air than a surface attack.

84. Rainclouds may form an impenetrable barrier to centimetric WS sets, and the possibility of an enemy unit being within or behind a raincloud must not be forgotten. Such a case has in fact occurred in the Pacific.

85. Even if the enemy knows our approximate bearing, from interception, reconnaissance or intelligence, it is to be hoped that our radar will detect him before he detects us. As the range closes, however, he will doubtless make detection: it may be possible to deduce the moment of his doing so by observing his movements (e.g., a sudden alteration of course) on the plot.

CHAPTER VIII

USE OF RADAR IN A/S WARFARE

The use of radar in anti-submarine warfare is a particular case of its tactical application, and the remarks in *Chapter VII* apply generally. There are, however, some special problems in the A/S sphere, and the subject therefore requires amplification.

2. The three main detecting instruments used to detect U-boats are H/F D/F, Radar, and Asdic. These operate at relatively long, medium, and short range but they are complementary and where all three come into play the target is "passed" from one to the other. Thus an A/S escort may move out on the evidence of H/F D/F bearings, gain contact and close by radar until the U-boat dives, and carry out the final attack by asdic.

3. If the U-boat attempts to escape on the surface, or is disabled, ships fitted with "Squid" can use Radar information to carry out a "Squid" attack. (See *para. 40* below.)

SPECIAL CONSIDERATIONS AFFECTING THE USE OF RADAR FOR A/S PURPOSES

4. The following are the special considerations which affect the use of radar for A/S purposes.

Range

5. A U-boat is one of the smallest targets which radar is required to detect operationally, and the detection range is relatively small. Typical ranges obtainable by sets fitted in small vessels are:—

Type	Where Fitted	Range in Yards against surfaced U-boats
277	Frigate	12,000
SG1/a	Frigate	12,000
SL	Frigate	11,000
293	A.A. Sloop	10,000
273Q	Corvette	9,000
271Q	Corvette	8,000
272P	A.A. Sloop	5,000
291U	Trawlers, Minesweepers, MGB/MTB and M.I.s.	3,500

6. These are reliable ranges obtainable under good conditions, and maximum range may be greater. Under poor conditions, *e.g.*, in rough weather or with interference from side echoes, the effective range may be considerably less. Periscopes may be detected in fine weather at about one-third of the figures given in *para. 5*, but in rough weather periscope detection is fortuitous. Clearly the technique of U-boat detection by radar demands alertness and quickness off the mark at all times.

Ground wave and wave clutter

7. With the U-boat at very close range, difficulty in gaining and/or holding contact may be caused by the ground wave and wave clutter, especially on a rough day. These can be reduced to 200–300 yds. by switching to short pulse and turning down the receiver gain or P.P.I. input, and accepting temporary loss of detection of more distant targets. It will be found easier to follow the target among sea returns on P.P.I. than on "A" display, but once the target enters the ground wave (if he has not dived by then) it will be necessary to hold the echo and use "Watson effect" on "A" display.

Discrimination

8. While searching for U-boats, whether on "A" display or P.P.I., long pulse length and ample receiver gain (or P.P.I. input) should be used, since this gives the maximum detection range. After detection, however, and as the attack develops, trouble is frequently experienced from side echoes or shadow areas from ships of the convoy or the unit being screened, or from other hunting vessels. Under these circumstances better discrimination must be obtained by switching to short pulse length and/or turning down the receiver gain (or P.P.I. input). At close range it may be necessary to stop the sweep and use hand training and "A" display for getting accurate bearing, owing to the wide echo on P.P.I.

Side echoes

9. With powerful modern centimetric sets such as types 271/3Q, 277 and 293, large vessels may give side echoes at ranges which approximate to the first detection range of a U-boat. This is naturally very confusing. Therefore, when a new echo is detected with these sets at a range of 10–12,000 yds. or less, the operator must invariably check for side echoes. This is done when using "A" display by training right and left to locate the main echo (if any); when using P.P.I. the side echoes should immediately be apparent as such by their symmetrical position each side of the main echo. In either case the gain or input should be adjusted as necessary.

False echoes

10. (See Chapter V.) False echoes whether from rain, birds, or any other cause, most frequently appear at short range and may cause an alarm. They should soon be apparent for what they are by the intermittent type of echo, or by plotting their movement. The operator should not however be discouraged from reporting them immediately, and classifying them later.

Radar Decoy Balloons (R.D.B.)

11. These are used by U-boats to mislead escorts. The device consists of a hydrogen filled balloon connected to a small metal float by a single strand of nylon 150 ft. to 200 ft. long. Three strips of metal foil are attached at intervals to the nylon line which fly like pennants and which act as the reflectors. In good conditions the decoy has been detected at ranges up to 15,000 yds. by type 271Q and at ranges up to 6,000 yds. by type 291. The echo is similar to that of a fully surfaced U-boat but fluctuates if anything rather more rapidly than a U-boat echo. With type 271Q at ranges less than 3,000 yds. the decoy echo can be distinguished from the U-boat echo by the absence of "Watson" effect.

12. If a U-boat echo is available for comparison, as in the case of a U-boat actually releasing an R.D.B. while being held by radar, the R.D.B. is fairly easily identified as such. If no U-boat is available for comparison, an R.D.B. may be mistaken for a U-boat even inside 4,000 yds.

13. The decoy moves downwind at about two-thirds of the wind speed but it is unlikely that the decoys would be used in winds above force 6. The importance is stressed of starting a plot as soon as a suspicious echo is detected. The fact that echoes travelling in directions other than down wind cannot be due to decoys may be the only means of differentiating between decoys and U-boats.

IDENTIFICATION OF U-BOAT ECHOES

14. Owing to the comparatively short range of detection of U-boats there is not much time to deliberate on the identity of a new echo at medium or short range which is not showing I.F.F. Apart from the possibility of a decoy, the points to consider are:—

(a) Whether in a known U-boat area.

(b) Evidence from H/F D/F or Asdic.

If U-boats are known to be about, an unidentified echo first detected at the appropriate range should be assumed to be from a U-boat until proved to the contrary.

15. The requirement for rapid identification and the particular difficulties of achieving this in A/S warfare emphasize the need to keep the operator fully informed of the position of ships in company, and any changes in their position, so that he may more easily spot a new echo. He should also be given the course and any other information, including future movements, likely to be of assistance to him. He should be provided with a locally made mooring board, or similar diagram, on which to note the range and bearing of escorts, the limits of the convoy (or unit), and any other prominent echoes.

STATIONING AND CONDUCT OF A/S ESCORTS

16. The capabilities of the radar fitted will be a major factor in the stationing of A/S escorts or the type of A/S screen adopted at night or in low visibility. Although the U-boat will probably approach on the surface the screening dispositions cannot however be based entirely on radar. Other factors must be considered such as maximum asdic cover against a U-boat that may attempt to surface inside the screen, the best positions from which to attack or counter-attack, the need for filling the gap should one escort move out to investigate, and the requirements of H/F D/F and communications. It is desirable, also, should numbers permit, to have both an outer (radar) screen and an inner screen, the latter placed so as to form a physical obstruction or so as to be able to attack U-boats surfacing within the outer screen. Detailed orders and diagrams are to be found in appropriate instructions (A.C.Is., Manual of Anti-U-Boat Warfare, Signal Manual, etc.) depending on the particular operation.

17. From a purely radar aspect it would be possible to extend the distance between escorts to twice the reliable detection range of a U-boat taking into account the weather conditions. The limitations of certain sets in ships must, however, be remembered; for example, in certain destroyers the WS set is blanked forward, while in other ships it is blanked aft. Type 271/3 is not a convenient set to operate in astern positions because of the aerial stops.

Action on obtaining a suspected U-boat echo

18. The action taken by an escort on obtaining a U-boat echo will, of course, conform with operation Orders, and the following is given only as a guide so that those concerned with radar can appreciate the way the situation is likely to develop.

19. When the echo is confirmed as "unidentified" or "hostile" a report is made to the Senior Officer and other ships, usually by R/T. In the ship herself action stations are assumed and the armament brought to full readiness.

20. The detecting ship will normally close the suspicious echo at maximum speed until within asdic range when the speed will be adjusted for an efficient asdic sweep to be made which will be commenced either side of the radar bearing. Due regard, however, must be paid to the provision of anti-Gnat tactics.

21. If the U-boat does not dive, action using the Squid or gunfire will follow and accurate range from radar will be required. If it is decided to ram it will be necessary to hold the target for bearing and range using "Watson" effect.

22. If the U-boat does dive the fact should be known from the disappearance of the echo, and it may be expected that she will be picked up by asdic and attacked with depth charges.

Other escorts

23. Until the echo is identified as that of a U-boat other escorts are unlikely to take action other than moving across to cover the gap caused by the detecting ship moving out to investigate. Once the identity of a U-boat has been established other escorts may be detailed to join in the hunt.

Convoy or unit being screened

24. When the alarm is given the convoy or unit being screened may be ordered to take drastic avoiding action, usually away from the suspicious echo.

Detection and Controlled Interception by large ships

25. As explained in *Chapter VII, paras. 52-55*, a large warship may detect a U-boat at about twice the range obtainable from an escort. In such a case the large ship may direct the movements of the escort until the latter has detected the target.

CONTROL AND USE OF RADAR

26. For A/S purposes control of the WS radar set is exercised from the Operations Room, or in small ships direct from the Bridge if the Operations Room is not manned. The controlling position is responsible for giving all instructions and information to the radar office as described in *Chapter VII, para. 63*, and normally the WS set is always used when the visibility is less than the maximum detection range of a U-boat. As stated in *para. 15* of this chapter, it is most important to keep the radar office fully informed of the position and movements of ships in company.

Type of sweep (all round or sector) and rate of sweep

27. Either all round or sector sweep can be ordered. With *new sets* (types 277, 293 and SG) continuous all round sweep is the normal procedure, using the normal rate of sweep for surface warning (6 r.p.m. for type 277, $7\frac{1}{2}$ r.p.m. for type 293). Sector sweep should only be employed when it is desired to obtain maximum range of detection over a small arc, *e.g.*, if a U-boat's approximate bearing is already known, and even then an occasional all round sweep should be ordered for the reasons given in *para. 33*.

28. With *old sets* (types 271/2/3) the lack of continuous rotation combined with the slow training complicates the decision between all round and sector sweep. In fact the theoretical probability of detecting a U-boat at a useful range depends upon three factors, namely, the maximum possible detection range, the rate and extent of sweep, and the relative direction and speed of approach of the U-boat; and with old sets this probability varies between 0% and 100%.

29. The decision whether to order all round or sector sweep should be based on the following consideration:—

- (a) If there is a chance of a U-boat surfacing inside the screen an all-round sweep should be carried out.
- (b) If the number of escorts is inadequate to form a complete radar screen, an all-round sweep should be carried out. There will be thus a good chance of detecting a U-boat which has penetrated the screen outside radar range of any escort, but which subsequently comes within range of an escort on the inner arc of its sweep.
- (c) When sufficient escorts to form a complete radar screen are available, and the chances of a U-boat surfacing inside the screen are remote, the use of a "sector" sweep should slightly increase the initial detection range. The sector sweep may be from adjacent escorts outwards or from the edges of the convoy or unit being screened. A sector sweep also has the slight advantage that most operators detect new echoes most readily if the arc they are given to sweep includes very few echoes.
- (d) When conditions of high speed make a sweep over part of the arc astern unnecessary, a sector sweep should of course be used.
- (e) In cases where a sector sweep is used an occasional all-round sweep should be ordered.

30. In order to increase the probability of detecting a U-boat old sets when *not fitted with P.P.I.* always sweep from aft to forward, on either side of the ship alternately, with a "bow overlap" of 20°; except where the arc of sweep extends less than 40° on one bow when the sweep on that side may be from forward to aft. The rate of sweep is 180° a minute in calm weather and about 90° a minute in rough weather and when investigating an arc.

31. When *fitted with P.P.I.* the rate of sweep should normally be 360° a minute, the sweep being continuous from aft through ahead to aft again, alternately clockwise and anti-clockwise.

32. Under certain circumstances it may be necessary to *hold* the target and sacrifice all-round lookout, *viz.* :—

- (a) When investigating a particular contact.
- (b) In order to get more accurate bearings for the plot when the target is at close range.
- (c) In "Squid" fitted ships, when necessary to provide accurate ranges and bearings for control of the "Squid."
- (d) In order to establish the exact time when the U-boat dives.

33. In the above circumstances it is advisable to order an occasional all-round sweep for the purpose of :—

- (a) Detecting any other U-boat which may be in the vicinity.
- (b) Closing the gap in the screen as far as possible.
- (c) Confirming the position of the ship relative to the convoy or unit and other escorts.

Range scale to use

34. Both with old and new sets the 15,000 yds. scale should normally be used for A/S work. This gives the best discrimination and accuracy, and a U-boat is unlikely to be detected outside this range even under anomalous conditions. In order to detect larger targets, an occasional sweep on the 75,000 yds. scale should be carried out.

Use of radar for station keeping in convoy

35. It is important that the use of the WS radar set for station-keeping should not be allowed to interfere more than absolutely necessary with the A/S function. Thus in sets with no P.P.I. the number of ranges and bearings required of the convoy or unit being screened, or of other escorts, should be kept to a minimum. This also applies to a lesser degree when P.P.I. is fitted, as continually reporting details of the convoy tends to distract the operator from spotting new echoes, which is his primary task.

Co-operation with asdic Officer

36. Since the echo of a U-boat may often pass from radar to asdic, and sometimes *vice versa*, there must be the closest co-operation between the two offices, *via* the Operations Room or Bridge.

37.-39.

USE OF RADAR WITH SQUID

40. The squid throws a pattern of three or six projectiles ahead of the ship and radar information can be used to place the pattern correctly. It is necessary to hold the target by radar, and ranging is carried out on a modified "A" display in types 271/3Q and 277, using a range scale of 0-3,500 yds. A dip in the trace is aligned with the echo and the range is transmitted automatically by Ranging Outfit R.T.C. with accuracy of 10-15 yds. to the Asdic range recorder where it is plotted against time in the same way as Asdic echoes. (The Asdic echoes also appear, if in contact.) The rate of closing is thus computed and this gives the correct time to fire. The radar bearing is also transmitted to the Asdic Bearing Recorder which gives course to steer, puts the Squid on to correct bearing, and keeps the Asdic oscillator on the bearing of the U-boat.

CHAPTER IX

USE OF RADAR FOR NAVIGATION

1. The assistance which radar and similar radio methods can provide for navigation and station-keeping is so obvious as hardly to need emphasis. There have been numerous instances of ships making long voyages at high speed, entering harbour, or making a rendezvous under visibility conditions when the feat would seldom have been attempted in pre-radar days. In the future, we may expect that radar will play an even more general part in preventing loss of life at sea.

2. It must be realised, however, that radar is only an additional aid to navigation; it has its limitations, as described below, and it is still necessary to make use of all other available information.

3. The surface warning set is used for navigation, and the information is therefore obtained *via* the Operations Room unless it is decided in special cases to control the WS set direct from the Bridge. The remote P.P.I. display in the Bridge Plotting Room (and on the Bridge, if fitted) will prove of value. It is assumed in these notes that a P.P.I. is available.

CAPABILITIES OF RADAR FOR NAVIGATION

Range

4. The WS set is a good detector of land, and very considerable ranges of the order of 100 miles have been obtained against high peaks such as Teneriffe, especially under anomalous conditions of propagation. Any bluff headland such as Dunnet Head will give excellent reflection, but sloping land is not so good since the radar beam tends to be reflected upwards instead of back to the receiver. Small islands are detected at ranges equivalent to those of ships of similar height and mass. Icebergs and growlers can be detected, the range again depending on their mass and height above water. (Ranges of 10,000 yds. against a 70 ft. iceberg were obtained with type 271P and should be exceeded with more modern sets.) Buoys can be detected at useful ranges, somewhat less than that of a U-boat; exact figures cannot be given because the size of buoys varies considerably.

5. It is important to realise that the beam of a WS radar set is comparable to a pencil of light, such as a searchlight, but inclined upwards at a small angle to the horizontal. It will therefore be appreciated that, except at close range, it is improbable that low lying land will be detected whereas high land beyond it will almost certainly be detected. In these circumstances the off shore distance, as given by radar, would be incorrect. The curvature of the earth also adds to this error.

6. Again, using the analogy of the searchlight, it will be realised that high land will screen lower land which lies beyond it, and the radar picture presented therefore generally consists of a number of patches, and not a solid paint.

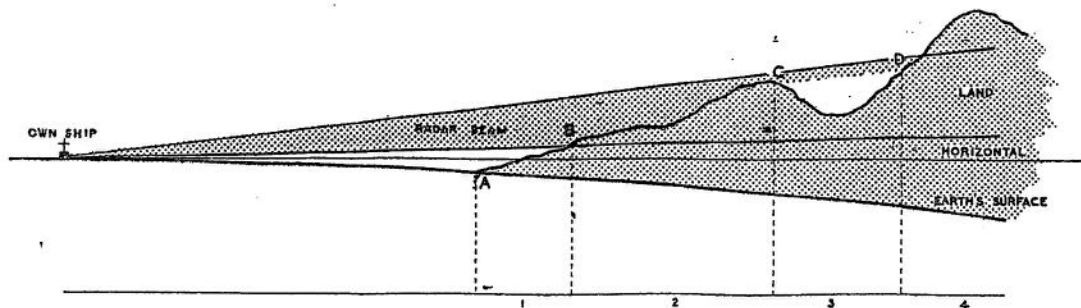
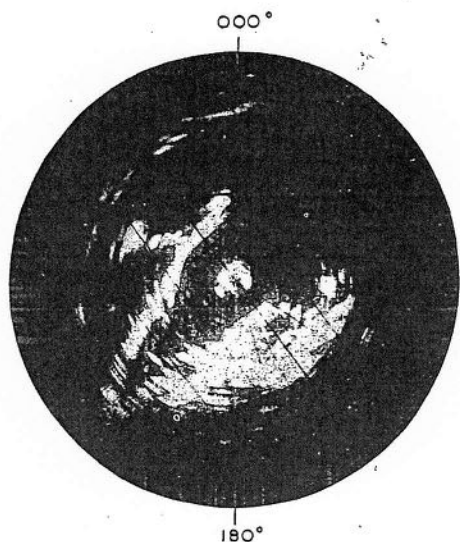


Fig. 34—Effect of upward inclination of the radar beam, and earth's curvature, on detection of land.

- 1.—Land not detected. Too low.
- 2.—Land detected.
- 3.—Land not detected. Obscured.
- 4.—Land detected.

7. These points are illustrated in Fig. 34, where the effects have been somewhat exaggerated. The foreshore from A to B is not detected, while the land from B to C casts a shadow so that the land from C to D is obscured.

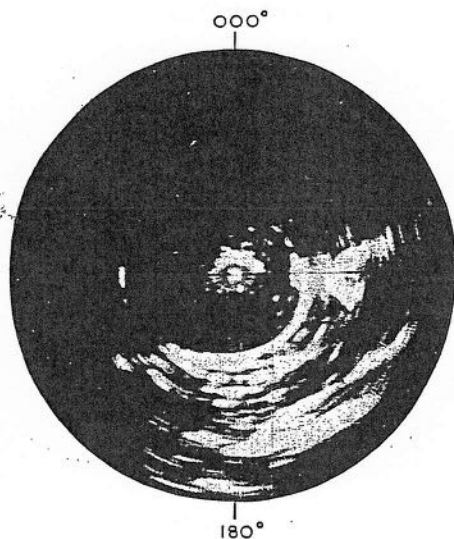
GROUP IV.



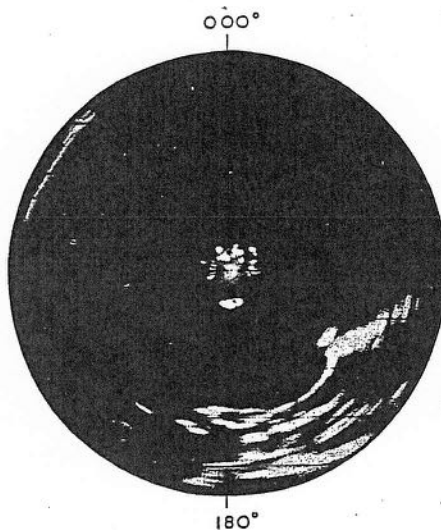
PHOTOGRAPH 60—P.P.I. view of Moray Firth, taken from Position X (figure 35) using WS type 970 on 25-mile scale; with input in normal "warning" position.



PHOTOGRAPH 61—The same view as in photograph 60, but with the input turned down to improve discrimination and reduce the shadow areas, thus enabling more accurate ranges and bearings to be read off.



PHOTOGRAPH 62—P.P.I. view of Burghead Bay taken from 3,000 yards off shore, using WS type 970 on 7-mile scale, with input turned down. A ship is shown bearing about 270°.



PHOTOGRAPH 63—Another view of Burghead Bay taken from 6 miles offshore from position Y (figure 35). The ship in photograph 62 has closed and is now bearing about 180°. The coast to the north-west of the Firth also appears on this view.



PHOTOGRAPH 64—P.P.I. view of Inverness Firth taken with WS type 970 from position Z (figure 35). 3 ships, showing side echoes, can be seen bearing approximately 040°.



PHOTOGRAPH 65—P.P.I. view taken off Isle of Man using WS type 277 on 0-15,000 yard scale, with input turned down. The southerly headlands of the Island show up well, and the Calf of Man and the "Chickens" stand out as separate echoes. Two ships are shown, bearing 170° and 230°.

8. The range accuracy of WS radar sets when using "A" display is about 200 yds. on the 15,000 yd. scale, 300 yds. on the 75,000 yd. scale, and 500 yds. on the 150,000 yd. scale. Using P.P.I. the figures are about double. This is usually adequate for navigation, though care should be taken where necessary to see that the Index Correction has been applied. When greater accuracy (10-20 yds.) is required, it would be necessary to use one of the Gunnery ranging sets; these have "A" display only, and no P.P.I.

Bearing and effect of beam width

9. On comparatively small isolated objects such as the Eddystone Lighthouse, bearing accuracy should not exceed 1-2°, and may be better. When viewing a coast, however, trouble arises due to the width of the radar beam or horizontal coverage diagram which is effectively greater than for ship detection at the same range, because of the greater reflectivity of land masses. Consequently, as the radar aerial sweeps along the coast an echo will still be received some distance after the centre of the radar beam has passed headland and is pointing out to sea. This results in the bearing of the headland as shown on P.P.I., being in error.

10. The effect of side lobes is usually pronounced when near land. Side lobes have the effect of showing echoes where no land exists and generally confusing the P.P.I. picture.

Radar shadow area

11. As explained in *Chapter VII* and illustrated in *Fig. 28*, another effect of the width of the radar beam is to throw a "shadow area" along the coastline, so that not only may the apparent bearing of a headland be in error but also the shape (and therefore apparent range) of the coast line may be incorrect. The shadow area and its effect will be least for that part of the coast which runs at right angles to the observer, and will be greatest when the coast is viewed obliquely.

12. The effect of the radar beam width in "spreading out" the land circumferentially also means that the width of an opening such as the entrance to Invergordon, will appear less than it really is; and in some instances the opening may not be apparent at all. Also, if a bay is flanked on one side by high cliffs and on the other by lower cliffs, the apparent bearing of the centre of the bay will be in error. The true bearing will lie more towards the side of the higher cliffs.

Range versus Bearing

13. It follows from the remarks in *paras. 5 and 11* that the apparent range may be *too great* on account of the upward angle of the radar beam or *too small* on account of the shadow area thrown by an adjacent piece of coast. When ranging, therefore, a part of the coast should be chosen which is as bluff and protruding as possible and whose general line lies at right angles to the observer. Provided this is done the range should be accurate.

14. On the other hand there is no simple rule for obtaining good bearing (except of isolated objects) or of estimating the amount of error. The best that can be done is to turn down the P.P.I. input so that the point is just showing, *i.e.*, so that the beam is as narrow as possible.

15. Therefore, unless the P.P.I. picture obviously bears a close resemblance to the chart, it is usually better to **fix the ship by two or more ranges** than by range and bearing, or by two bearings.

Discrimination

16. The usual methods as explained in *Chapter VII*, are employed to improve discrimination and generally "sharpen" the P.P.I. display for navigation. These include using the shortest practicable range scale and reducing the P.P.I. input, remembering that maximum warning is temporarily lost. If the shortest range scale is being employed greater detail is also obtained by using short pulse length.

INTERPRETATION OF P.P.I.

17. Two pairs of actual P.P.I. pictures, *Photographs 60 and 61*, bring out many of the above points if they are compared to a chart of the area (*Fig. 35*).

18. *Photograph 60* is taken from the middle of the Moray Firth, from the point marked X in *Fig. 35*, using type 970 on the 25 mile scale. Normal P.P.I. input is in use, and the display shows correct "healthy" background which is the correct condition for good surface warning. The resultant side echoes confuse the picture of the land. In *Photograph 61* the input has been turned down to obtain better discrimination and accuracy for navigation.

19. The most noticeable feature of these views is the sharp definition obtained from the straight bluff coast from Cromarty to Tarbat Ness, compared to the indeterminate picture of the lower undulating coast from Nairn to Burghead Bay. Other points to notice are :—

- (i) With normal gain, the effect of the width of beam and shadow area is seen. The bearing of Tarbat Ness appears to be 10° higher in *Photograph 60* than *Photograph 61*, and even in the latter is actually 5° too high.
- (ii) Similarly the range of coast off Tarbat Ness appears as $7\frac{1}{2}$ miles in *Photograph 60* on account of the shadow area and oblique angle, whereas the true range of about 9 miles is shown in *Photograph 61*. This point would not in any case be a good one to range on : a better plan would be to take a point midway between Cromarty and Tarbat Ness, where the coast is at right angles to the bearing. In this case the range difference between the two conditions is negligible and the range of $6\frac{1}{2}$ miles correct.
- (iii) The entrance to Invergordon is better defined on *Photograph 61* than in *60*, though it is not well defined on either owing to the oblique angle.
- (iv) Dornoch Firth is not well defined, being blanked by the high land south-west of Tarbat Ness.
- (v) In *Photograph 61* turning down the input to get discrimination has had the effect of reducing maximum range and has removed all trace of the high land north of Dornoch Firth, except one peak (probably Ben Lundie).

20. *Photographs 62 and 63* show Burghead Bay using type 970 on the 7 mile scale. Here the P.P.I. input is at the same (low) setting in each case. In *Photograph 62* the offshore range is 3,000 yds., and in *Photograph 63* 6 miles (shown as position Y in *Fig. 35*). The point to notice here is the way the coastline is fairly continuous at close range, whereas at the greater range it becomes discontinuous because the low lying shore line is not all detected and many of the nearest echoes come from higher land beyond. Burghead Point, being prominent, stands out on the P.P.I.

21. In both *Photographs 62 and 63* the wave clutter can be seen round the ship, and another vessel (an L.C.H.) can be seen also.

22. *Photograph 64* shows a ship in position Z (*Fig. 35*) following three others, from whom side echoes are visible, out of Inverness Firth. Points to notice are :—

- (i) The generally discontinuous line of the low lying coast, especially to the South, where the range is greatest. The land off Chanonry Point and Alterlie Point stands out clearly, however, as does also the entrance to Munlocky Bay. These would be good points to range on.
- (ii) The bearing of Chanonry Point is about 5° too high owing to the radar beam "spreading out" the land.

23. The above P.P.I. pictures were, of course, taken under comparatively favourable conditions, i.e., the coast was sufficiently close for most of it to be detected, and not too close and surrounded for the picture to become congested or distorted. At long range, when the coast is first picked up, it may bear no resemblance to the chart at all, since only high peaks in the hinterland may be detected. As the coast is closed, however, the resemblance to the chart will emerge, gradually at first and more rapidly as low land is detected.

24. It must also be emphasised that when a land echo is first detected, it should not at once be assumed that it is the particular point which it was expected to make. Coming down from the North of Scapa, a cruiser once "made" North Barra Island by radar. The subsequent detection of large land masses ahead proved that "North Barra" was really Sule Island. Fortunately, surface radar will always give good warning of land ahead. But it cannot detect submerged rocks.

Reporting information from P.P.I.

25. When navigating from P.P.I. and a series of ranges (and/or bearings) is required, it has been found convenient to instruct the operator to refer to the selected points by letter, rather than by their proper (and possibly long-winded or unpronounceable) names. The Navigating Officer then asks the operator for, say, ranges of A, B and C and these are read off and reported in that order. The selected points (or sketches of coast) must, of course, previously be explained to the operator who should also be provided with a chart with the points marked on. It should be explained to the operator that the P.P.I. and chart scales are not the same.

26. Another method of fixing from the P.P.I. which has been used with success by the U.S. Navy, and which may be of value during bombardment as well as for navigation, is designed to minimise the difficulty of the difference between P.P.I. and chart scales. At a convenient position on the chart a range scale is drawn, marked in yds. to the scale of the chart. A template made of tracing paper or perspex is constructed with radial lines drawn at 5 or 10 degree intervals so as to cover an arc of about 220 degrees. The centre of the template is pinned to the zero of the range scale on the chart.

27. The radar operator is then ordered to take P.P.I. ranges of the nearest point of the land at 5 (or 10) degree intervals from one end to the other of the pre-arranged sector. The navigator marks each range on the corresponding radial line on the template, rotating the latter to bring succeeding true bearing lines over the range scale. The points obtained are joined and thus form a reproduction of the P.P.I. picture, but to the scale of the chart, and this reproduction is then fitted to the best position on the chart. The centre of the template will then show the ship's position at the middle time of ranging.

28. It is claimed that a fix can be obtained in under a minute and that this method minimises the effect of:—

- (a) uncertainty as to the point or points of land being ranged on.
- (b) slope of the land producing ranges from behind the shore line.
- (c) errors in bearing due to the width of the radar beam.
- (d) unknown gyro error.

29. It is claimed that under favourable conditions for radar, *i.e.*, where there is a sufficient amount of characteristic coast line under detection, this method of fixing is consistently superior to other methods. Where a good large scale chart is available fixes have been obtained from a position about 8 miles offshore with an apparent error of only 200 yds. In addition this method avoids drawing a large number of lines on the chart.

30. The method would however be unreliable:—

- (a) If the coast line is straight and low lying, or if there is insufficient coast line under detection.
- (b) If the chart is inaccurate or incomplete.

P.P.I. Charts

31. As explained more fully in *Chapter XVII*, it is possible to predict what the P.P.I. picture should look like from various offshore bearings and distances, and to produce "P.P.I. Prediction Charts" for accurate navigational use in Combined Operations. Owing to the considerable labour involved and the fact that the picture alters with different sets and for every offshore position, it is not at present intended to produce predicted charts for general use. However, appreciation of the points brought out in this Chapter and a certain amount of experience will produce results which are quite adequate for normal circumstances. It may also be found helpful to mark on the chart those points or portions of the coast line and hinterland which are likely to be detected best, *vide Fig. 65 in Chapter XVII*.

32.-36.

RENDEZVOUS

37. The normal capabilities of surface warning radar are used to effect rendezvous at night or in low visibility, but in the absence of I.F.F. response from the other ship or ships due caution as to identity must be exercised. Also, own ship must not forget to switch on I.F.F. whilst closing.

STATION-KEEPING

38. Radar is very useful for station-keeping, particularly when using remote P.P.I. which should for this purpose be switched to the shortest range-scale with the P.P.I. input well reduced so as to give good discrimination.

39. It is important to remember, however, that the primary function of the WS set is warning, and its use for station keeping must not be allowed to interfere with its primary function. The P.P.I. input should therefore not be kept turned down longer than is necessary, and where no P.P.I. is fitted only occasional ranges and bearings of ships in company should be called for as otherwise the reliability of all round cover will be reduced.

RADAR BEACONS AND SHORE RADAR

40. In order to assist navigation, a number of radar beacons have been provided ashore and are fitted on lighthouses or other prominent points where they can be supervised. This practice will no doubt be extended considerably.

41. Types of shore radar beacons at present used are:—

Type	Range	Bearing accuracy	For use with
253S	10-15 miles	3-5°	Interrogator types 242 or 243
256	90% optical	2-5°	Type 291

Details are in *Chapters III and XIV*. The range obtainable is influenced by the height of the beacon. The range given will normally be 200-500 yds. greater than the true range, the error being least when the response is being received at good strength.

42. Radar Beacons are all provided with Coding so that they can be positively identified. Details of their position and codes are contained, for the Home Station, in H.D. 335 "Navigational Aids in War." Abroad, the information is promulgated by C's-in-C. Operation is usually continuous.

43.-45.

46. **Shore radar** (*Chapter XVI*) is provided primarily for warning of approaching enemy aircraft or surface vessels, but all surface tracks are passed to Naval Plotting Rooms ashore and these have frequently been of great assistance to ships doubtful of their position. The procedure is for the ship to request her position by signal to the Flag Officer in charge of the area in which she believes herself to be, at the same time switching her I.F.F. to very wide (distress) code so that she can be identified.

47. The position of any ship showing distress code is then obtained by radar and passed through the Coastal Plot to the ship (or alternatively the ship is informed that she cannot be distinguished).

48. In general, the positions so given are reliable and accurate to within 2-3 miles or less. It is important, however, that the limitations of the system should be borne in mind. These are :—

- (a) In the absence of I.F.F., and if the ship has not been tracked all down the coast and "passed" from plot to plot, positive identification is not possible. Indeed, the ship requesting her position may be out of radar range, whereas another ship may be within radar range. Mistaken identity would thus arise. For this reason, it is unusual to volunteer a position unless I.F.F. (distress code) is observed.
- (b) Only a limited area is covered by shore radar.
- (c) Identification may be difficult if a large number of ships is present.
- (d) In the case of a convoy, echoes from larger ships may be detected but not those from smaller ones. This would give an inaccurate position for the head of the Convoy if small ships were leading.
- (e) Bad weather reduces the range of shore radar stations.

In view of these limitations a position given from shore radar should be regarded as an indication of the ship's probable position and not as a navigational fix.

49. Alternatively, shore radar has often been used to re-route units who are both under shore radar observation, but who have not yet detected each other by radar. Many awkward situations have thus been avoided, particularly on the E. Coast of the U.K. and in the Gibraltar Straits.

50. Again, a ship may be observed from the shore radar plot to be running into danger (minefield or land). In such a case she can be warned by signal *if she is positively identified*. Alternatively, the plot can order the shore lights to be switched on: Duncansby Head has been switched on in this manner on at least one occasion.

51.-56.

OTHER RADIO NAVIGATIONAL AIDS

57. Other radio navigational aids which should be mentioned are :—

- (a) **D/F.**
- (b) **Gee**, which consists of chains of shore transmitters, using pulse transmission. A Chain of 3 transmitters enables ships fitted with receiver outfit QH to obtain 2 position lines up to a range of about 150 miles from the transmitters. Accuracy of fixes varies with the ship's position relative to the transmitters and her distance from them. In the best possible positions where the range hyperbolae are close together and cut nearly at right angles the error of a fix may be as little as 400 yds. but this error increases with distance and may amount to several miles at extreme range when the hyperbolae are wide apart and the cut is poor.
- (c) **Loran**, which is similar to Gee but gives longer range (700 miles by day and up to 1,400 miles by reflected sky waves at night). The receiver is D.A.S.2 and the accuracy is of the same order as that of Gee.

CHAPTER X

USE OF RADAR FOR AIRCRAFT WARNING

By extending our "vision" of aircraft, radar confers benefits on everybody in the Fleet.

- (a) It enables all quarters to be brought to the necessary readiness to meet air attack; this includes organisations such as damage control as well as those manning the armament. Conversely it allows relaxation during quiet periods, and this is obviously of great importance particularly when nights are short. Owing to radar limitations we have not however reached the stage when everyone can "fall out" until radar warning is received.
- (b) It allows the Admiral time to re-dispose his squadron in the best way to meet air attack. This disposition may be quite different from that required for, say, anti-submarine protection.
- (c) It reduces the number of wasteful standing fighter patrols which need be kept in the air, and allows time for carriers to be turned into the wind to fly off.
- (d) Together with efficient R/T, radar makes possible fighter interception of enemy aircraft bent on attacking the Fleet and usually enables the attack to be disorganised before enemy aircraft reach the guns of the Fleet which are the final defence.
- (e) It provides a bearing which enables visual lookouts to pick up aircraft more quickly, and enables guns and directors to be trained in the right direction in advance.
- (f) At closer range it provides more precise target indication which enables the armament to be distributed in the best way for visual or blind fire.
- (g) It enables aircraft to be directed on to surface targets (*e.g.*, U-boats) which are out of sight.

THE THREE ZONES

2. In discussing how radar provides the above facilities it is convenient to consider three zones (*see Fig. 36*):—

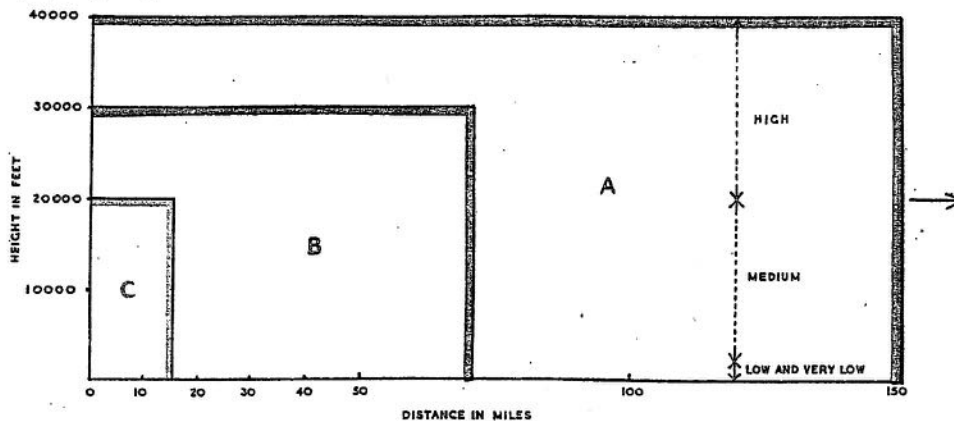


Fig. 36—The three aircraft detection zones, showing coverage requirements for:

- A—Warning zone.
- B—Fighter Interception zone.
- C—Target Indication zone.

- (a) **The Warning Zone** which is dealt with in this chapter and which is obviously required to extend as far as possible and up to say 40,000 ft. The ideal is to have a warning zone which extends far enough to avoid keeping any standing fighter patrols at all, by giving the necessary warning at each height to enable fighters to be flown off and climb in time to intercept at the outer limits of the Fighter Interception zone. This would require detection at ranges of the order of 100 miles (at the lowest heights), rising to 200 miles or more. This requirement cannot be achieved at present, particularly at low heights.

Apart from the range, the primary requirement for radar in the warning zone is *reliability* of detection. Great precision of location is not necessary. Approximate heightfinding is required, *i.e.*, "High," "Medium" or "Low."

- (b) **The Fighter Interception Zone.** This is the zone in which it is hoped to carry out actual fighter interception of enemy aircraft and must extend sufficiently far, say to 70 miles and up to 30,000 ft., to allow for a chase and combat before the enemy aircraft come within sight of the Fleet and preferably before they come within A.S.V. range of the Fleet and could report its presence.

Apart from the range, the radar requirements for this zone are greater precision and discrimination than are necessary for the warning zone, and also radar plan display. The accuracy must be sufficient to enable fighters to make contact visually or by A.I. (*see Chapter XVIII*). Accurate heightfinding is also a necessity, since it is just as easy to miss interception in the vertical as in the horizontal plane.

The radar methods used for Fighter Direction, including Heightfinding, are dealt with in the next chapter.

- (c) **The Target Indication Zone.** Assuming that some enemy aircraft elude our fighters and press home the attack, as is bound to happen, radar is required to provide a plan display, out to say 15 miles and up to 20,000 ft., in order that the H.A. gun armament (long and close range) can be distributed to the best advantage.

This requires a high degree of precision in location and discrimination, and also a rapid rate of aerial spinning in order to keep the information absolutely up to date and compete with targets at close range with a high rate of change of bearing. Height-finding is desirable but not vital, as the latest gunnery radar sets can themselves find elevation once they have been put on for bearing and range.

The radar methods used for Target Indication, and the present Target Indication radar set (type 293), are dealt with more fully in *Chapter XII*.

How requirements in the warning zone are met

3. As stated above, the ambitious range requirements for the warning zone cannot at present be met. There is no technical difficulty about high aircraft (above 20,000 ft.), it being only a matter of finding space and topweight for a larger aerial and more powerful transmitter, but at lower heights the curvature of the earth sets a limit to what can be achieved.

4. In addition to this, it must be emphasised that with long range aircraft warning, **one set alone cannot provide complete cover** at all heights. This is because of gaps in the vertical coverage diagrams, and the different characteristics of each type which are dictated by the wavelength used. Thus type 79 gives good high cover, type 281 good medium cover, and type 277 good low cover, and where complete cover is required in one ship all three sets must be operated in conjunction, thus providing a complete air warning system. This is in fact done in Fleet Carriers. In Battleships and Cruisers which have only one WA set, the object must be achieved by detailing suitable guardships and pooling results. With this end in view it is the present policy to retain type 79 in 25% of large ships, type 281 being fitted in the remainder.

5. *Fig. 37* makes clear how high, medium and low cover is obtained by the use of three sets.* Of course the total coverage is not as great as would be desired, but it is the best that can be achieved by a combination of present sets. By mounting types 79B and 281B at suitable relative heights in the same ship the former can be made to fill in the "gaps" of the latter completely.

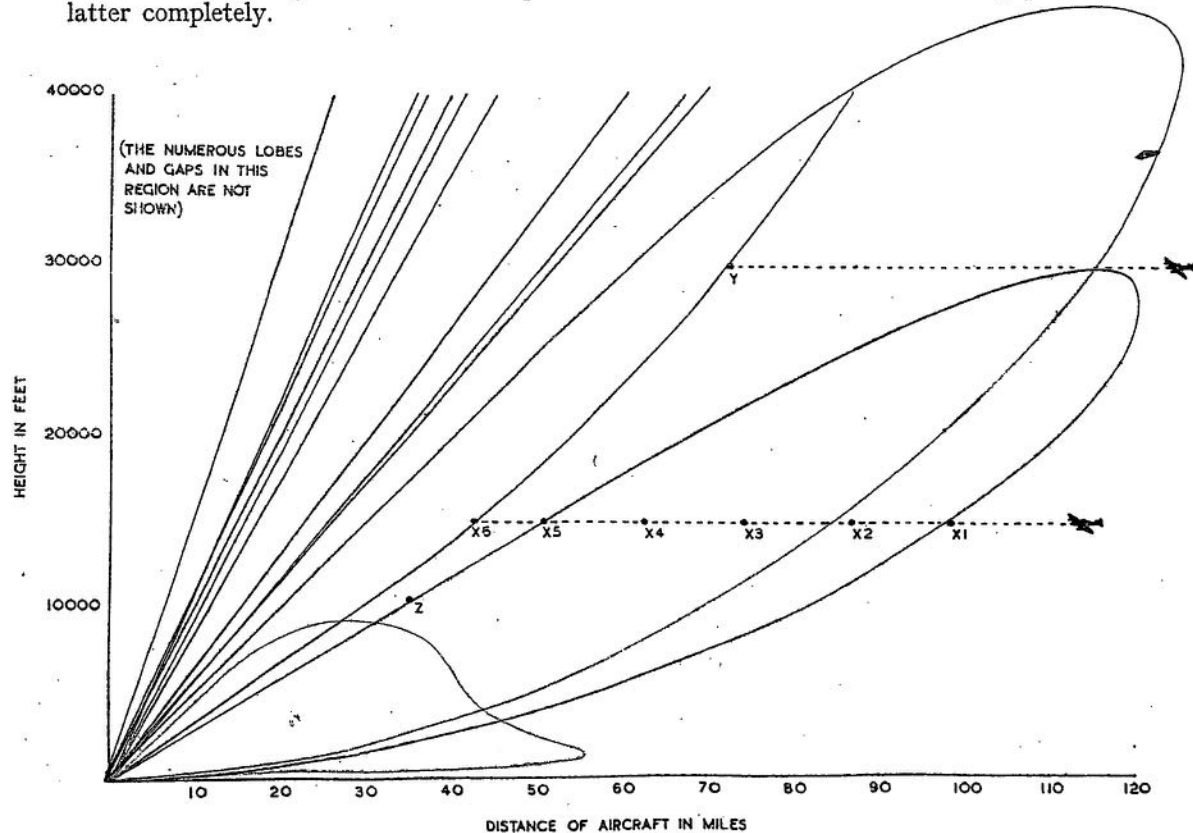


Fig. 37—Method of obtaining complete air cover by using three radar warning sets of different types, WA types 281B at 110 feet ——— WA Type 79B at 140 feet. ——— WS Type 277 at 100 feet. This figure also illustrates how WA sets are used for height finding, vide Chapter XI.

* High=20,000 ft. and above.
Medium=20,000–2,000 ft.
Low=2,000–200 ft.
Very Low=Below 200 ft.

6. It need hardly be emphasised that to maintain cover it is necessary for the warning sets to keep sweeping. The following will militate against reliable cover :—

- (a) If type 79 (which has no plan display) is required to watch too many targets. This involves stopping to get the bearings of each, and so slowing up the effective sweep rate. In the meanwhile a new target may be approaching from an unwatched bearing.
- (b) If type 79 is used for long periods for heightfinding. This too, *at present*, requires the sweep to be stopped, but means of avoiding this are under development, *vide Chapter XI, para. 33*. With good training fairly accurate heightfinding is possible with type 281, without stopping the sweep, if the sweep rate does not exceed 2 r.p.m.
- (c) When it is required to interrogate and read the I.F.F. Code, which *at present* requires the combined WA and Interrogator aerials to be trained on the target for 10 seconds. Means of avoiding this in future are described in *Chapter XI, paras. 14 to 17*.
- (d) When it is required to count the number of aircraft in a body, which necessitates stopping the sweep and using "A" display, *vide para. 35*.
- (e) If type 277 is used for heightfinding. This involves stopping and elevating the aerial.

Any or all of the above procedures may be necessary. What is important is to realise that, in the absence of guardships, reliable air cover has temporarily been surrendered.

HEIGHTFINDING

7. As far as the warning zone is concerned only very approximate heightfinding is required, *i.e.*, sufficient to tell whether the fighters should be positioned high, medium, or low. The approximate height can, with limitations dealt with more fully in *Chapter XI*, be ascertained by reference to the vertical coverage diagram for the range at which a new target is first detected, *e.g.*, in *Fig. 37* it would be about 15,000 ft. for the target X.

8. Unfortunately the more accurate heights required as the target approaches and enters the Fighter Interception Zone, and later the Target Indication Zone, have also at present to be obtained from the WA Set or sets, and type 277, and this reacts on the reliability of air cover as explained above.

RADAR DISPLAY

9. Continuously rotating aerials and plan display (P.P.I.) are very desirable for aircraft warning sets, since

- (a) they enable bearing and distance of targets to be reported with adequate accuracy and without stopping the sweep, and therefore avoid interfering with all round cover ;
- (b) many more plots per minute can be told from P.P.I. than when using "A" display.

Continuous sweep should therefore be the normal method of operation where P.P.I. is fitted.

SETS USED FOR AIRCRAFT WARNING

10. The following are brief details of the radar sets used for aircraft warning. Fuller details are contained in *Chapter III*.

Large Ships

11. Type 79/279/79B was the first WA set, and is noted for its reliability. Owing to the comparatively long wavelength :—

- (a) it detects high aircraft well (110 miles at 30,000 ft.), and it has fewer "gaps" than type 281 ;
- (b) its performance is only moderate against medium aircraft, and poor against low aircraft.
- (c) because of the wide horizontal beams, plan display is impracticable and hand training with "A" display must be used. This slows up reporting and sweeping.

12. WA Type 281/281B was designed as type 79's successor. Owing to the shorter wavelength :—

- (a) It is not so good on high flying aircraft which may fly over the first lobe and not be detected till they reach the second, at a much shorter range. (See Y in *Fig. 37*.) There are more gaps in the vertical coverage diagrams and therefore less continuous tracking is possible.
- (b) It is better than type 79 against medium aircraft (105 miles at 15,000 ft.), but still not a good detector of low fliers.
- (c) The narrower horizontal beam just permits plan display. Though this is not very good it is good enough for warning purposes, and can also be used (on P.P.I. or Skiatron) for Fighter Interception.
- (d) Because the first lobe is lower and the power greater, type 281 suffers more from land echoes than type 79.

13. WA Type 281BM will include two important modifications :—

- (a) A pre-amplifier which should increase ranges 10–15%, reduce gaps, and improve high cover.
- (b) Continuous rotation which will improve plan display and also the reliability of cover since the aerial need not be trained alternately clockwise and anti-clockwise as with type 281/B.

14. **WA Type 960** is under development to replace type 281, but the type 281BM aerial will be retained in some ships. The increased power will give appreciably greater range. Where a larger aerial can be fitted (types 960M & P) the range will be still further increased, and gaps reduced, and the narrower beam will give better plan display and more accurate bearing. The cover provided by type 960P together with type 980 (see *Chapter XI*) will be sufficiently continuous to dispense with a second WA set in Fleet Carriers. Types 960M & P will also be capable of rapid wave change to help to defeat enemy jamming.

15. **WA (U.S.) Type SK** fitted in certain escort carriers has approximately the same performance as type 281B except that owing to the shorter wavelength the first lobe is still further depressed and the gaps are more numerous. It is therefore a good detector of medium aircraft, but less reliable than type 281 and much less so than type 79 against high aircraft.

16. **WS Type 277** being a high powered surface warning set is also a good detector of low and very low aircraft when layed on the horizon (40 miles at 1,000 ft., 25 miles at 200 ft.). The primary function of this set (except in carriers) is, however, surface warning and it may therefore not always be available for aircraft warning. Also it may be used for height-finding in which case the aerial will be stopped and elevated clear of the horizon.

17. **U.S. Types SP and SML**, which are heightfinding sets fitted in certain carriers, will give results equal to or better than type 277 against very low aircraft when layed on the horizon and greater ranges against higher aircraft, but the sets are likely to be in frequent use for heightfinding.

18. **WS Type 271/3Q and U.S. Types SG and SL** are capable of detecting low and very low aircraft at ranges of the order of 10-15 miles, and have been found of value for filling in the low gap, but owing to their comparatively small power cover is not reliable particularly if P.P.I. is not fitted.

19.-20.

Small ships

21. Small ships cannot normally be fitted with the heavy WA equipment, and have to rely on a WC set whose performance against aircraft is considerably less. The classification "WC" is actually rather a misnomer nowadays in most small ships where a separate WS or centimetric WC set is also fitted for surface warning. In such cases the WC type 291 or SA should be regarded more as a "low power WA set," and is used for limited aircraft warning, for target indication if no WC (T.I.) set is fitted, and also in certain circumstances for limited fighter direction.

22. **WC Type 291** is the standard low powered aircraft warning set for small ships and will detect medium aircraft at 30-35 miles and low aircraft at 20 miles or less. Owing to the low power and comparatively short wavelength it will not detect high aircraft at any useful range. The numerous gaps cause frequent fading and make heightfinding impracticable.

23. Nevertheless type 291 provides useful air warning within its limitations, and its reliability will be increased when P.P.I. and power training are eventually fitted.

24. **U.S. Type SA** is fitted in certain frigates. It is similar to type 291 but owing to the larger aerial gives ranges 15-30% greater. It has P.P.I.

25. **WS sets** such as types 271/3Q, 277, and U.S. types SG and SL give warning of low and very low flying aircraft at ranges slightly less than when fitted in a large ship.

26.-29.

LIMITATIONS OF AIRCRAFT WARNING RADAR

30. Some of the limitations of aircraft warning radar have already been mentioned, e.g., the weakness of certain sets against high or low aircraft, the presence of gaps in the vertical coverage diagram, and the inability of any radar to see below the horizon. Other limitations are described below.

Recognition

31. The Interrogator (type 243/M) fitted with WA sets at present rotates with the main set and for reasons explained in *Chapter XI* the normal I.F.F. response cannot be displayed on P.P.I. effectively. Consequently it is at present necessary to stop all round sweep in order to interrogate. This limitation is being overcome with type 281 by providing a separately controlled interrogator type 243Q for normal "A" band interrogation and replacing type 243 by type 941 which will show "G" band responses from friendly fighters direct on P.P.I. and Skiatron.

32. In small ships type 291 has an interrogator (type 242) which is omni-directional and obtains responses for range only. The type 242 fitted with the WS set is, however, directional and may be used to assist in recognition of aircraft if it is acceptable to interfere with the sweep of the WS set.

33. The absence of I.F.F. response from aircraft targets cannot be taken as positive proof of hostile identity. Though the present Mark III system is very much more reliable and more widely fitted than its predecessor there is always the possibility that the I.F.F. (or the Interrogator) may not be working efficiently. Alternatively, the aircraft may not be aware that ships are operating in the vicinity and may therefore not have switched on its I.F.F.

34. It is therefore necessary to consider other evidence before classifying an aircraft target as "Unidentified" or "Hostile," *e.g.*—

- (a) whether friendly aircraft are expected ;
- (b) whether the direction of approach is from an enemy base ;
- (c) whether the movement of the aircraft indicates its intentions, *e.g.*, attackers working up sun ;
- (d) whether the numbers reported are suggestive of an attacking force ;
- (e) information from "Y" sources.

Classification of echoes

35. Aircraft echoes can fairly quickly be classified as such because of their fluctuating appearance, by the speed with which they move, and by their periodical fading as they pass through gaps in the vertical coverage diagram. It is not so easy to determine the number of aircraft in a body, and it is necessary to stop the sweep for a short period and study the echo closely on "A" display. After doing this a good operator should be able to differentiate between a "group" (more than 6) a "few" (2 to 6) and a "single," though it is common for a single to be reported as a "few" either because the target is a large aircraft or because the operator wants to be on the safe side. Operators will not improve in this respect unless they are told afterwards what actually was in the air, and the A.D.R. should provide this information whenever possible if they wish for improvement.

Location accuracy, and plotting

36. Range accuracy of WA sets on long scale is about 1 mile which is adequate for warning purposes. Opportunity should however be taken to ascertain what index correction exists (it may be as much as 5 miles). This can be done using an aircraft flying at right angles on a known course, or by ranging on a series of distant and very prominent peaks. The Index Correction can then be "taken out" by adjustment at the set. For further details see C.B.4224/44.

37. Where two WA sets are fitted it is important to see that the scales at least agree : otherwise plots will be duplicated and confusion will arise. It should also be remembered that R.N. sets are calibrated in sea miles, and allowance for this must be made when exchanging information with the R.A.F. and Army Organisations who deal in land miles.

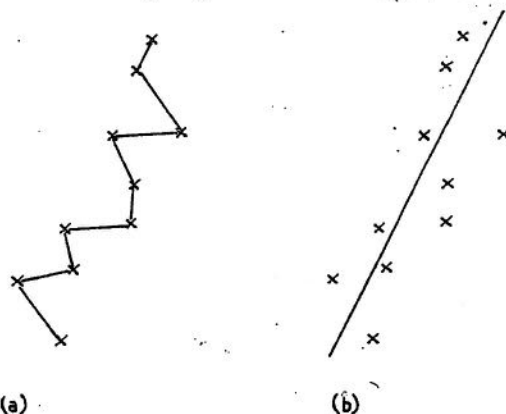


Fig. 38—Effect of poor bearing accuracy of WA sets on aircraft plotting. A mean track should be drawn through the points of detection, as in (b). The points should not be joined as in (a).

38. Bearing accuracy is the weakness of WA sets. This is due to the very wide beam of metric sets. Type 281 using P.P.I. gives about 3° accuracy, and type 79 with no P.P.I. gives only $5-10^\circ$; these figures may be bettered but they may also be worse if the bearing is changing rapidly. For this reason the plot of an aircraft is seldom a straight line but consists of a number of points which should not be joined, but through which a mean should be drawn, *vide* Fig. 38. It will require several plots (at least 3) before an aircraft's rough track can be estimated, particularly if it is flying nearly at right angles to the bearing, and several more before an accurate track can be deduced. Owing to the greater accuracy and consistency of bearing, better plots are obtained when telling from P.P.I. than from "A" display and telling from P.P.I. is also much quicker since the aerial need not be stopped.

39. The location accuracy of WS sets such as type 277 is much better, chiefly owing to the narrower beam and therefore better bearing accuracy, and an accurate plot of aircraft can be obtained correspondingly sooner.

Discrimination, and shadow areas

40. The range discrimination of WA sets is not good as a wide pulse is used in order to get maximum warning. In type 79 the normal pulse width is 11 microseconds which gives an effective range discrimination of $1\frac{1}{2}$ miles. In type 281 three pulse lengths are provided. The longest should be used except when more precise discrimination is required, *e.g.*, when operating a Skiatron for fighter interception. In this case the medium pulse length (5 microseconds) should be used and will give effective range discrimination of $\frac{3}{4}$ mile. This will not cause a very serious loss in warning range. Targets where bearings differ by less than the bearing discrimination of the set can only be plotted separately if their range differs by more than the range discrimination distances quoted above.

41. The bearing discrimination of WA sets is also poor, because of the wide horizontal beam. Thus targets at the same or nearly the same range, *viz.*, within the range discrimination distance, cannot be separately plotted unless their bearing differs by more than about 70° with type 79, or 35° with type 281 using P.P.I. With type 281 using "A" display (which is unusual) the figure is about 20° .

42. The combined effect of the beam width and range discrimination distance is that a "Shadow Area" is associated with every target, as illustrated in Chapter VII, Fig. 27. Within this shadow area other targets cannot be separately plotted, though the fact that several aircraft targets or groups of aircraft are present may be spotted by the unusual width of the echoes, or by the overlapping of several echoes.

Effect of land

43. The shadow area caused by land is serious in the case of WA sets, primarily because of the wide horizontal beam. Side echoes further confuse the display and are effective up to much greater ranges than against aircraft because of the reflectivity of large land masses. Type 281, having a lower first lobe and being more powerful than type 79, is particularly affected by land echoes and its operational usefulness may be seriously reduced up to 20 miles or more from high land. For inshore work type 79 is therefore to be preferred.

44. It may be mentioned that with experience in a particular harbour a good operator can obtain some results even when there are bad land echoes. Thus, during the North African Campaign, a cruiser at Bone got nil results for the first few days, but after a week was able to get useful warning of high fliers. Again, ships off Anzio developed some skill in seeing through land echoes: in this case it was found best to use the shortest pulse length and short range scale of type 281 (0-30 miles) in order to give the best possible discrimination.

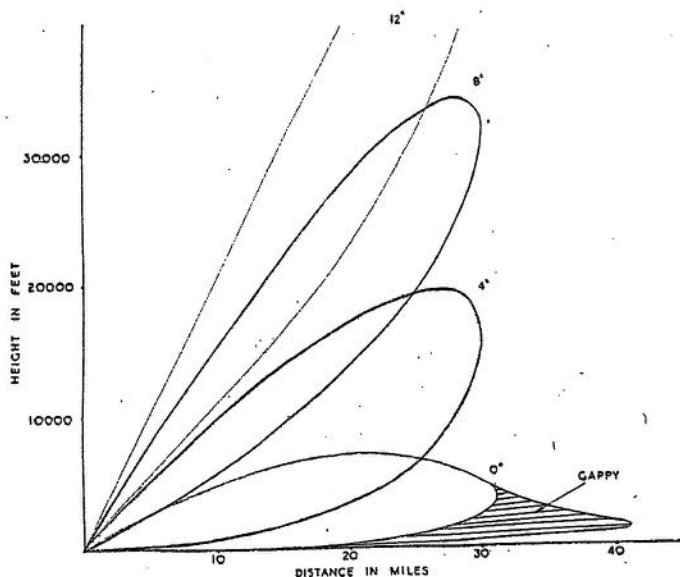


Fig. 39—Method of obtaining air cover by elevating WS type 277 in steps of four degrees. This method may have to be used for aircraft warning when in the presence of land or "Window," but is not recommended as a normal practice.

45. If land echoes absolutely prohibit the use of a WA set, consideration should be given to using WS type 277 whose narrow beam gives better discrimination. When layed on, the horizon, type 277 will detect aircraft up to 7,000 ft. at 25 miles. By elevating the aerial in 4° steps it would be possible to obtain similar range at greater heights. Theoretically heights up to 20,000 ft. could be covered in 4 steps as illustrated in Fig. 39. This procedure however will require good drill and considerable practice, and will never be entirely satisfactory (though it may be the only expedient).

Interference and jamming

46. WA sets use wavelengths which are particularly susceptible to interference from communications, of which R/T is the worst. Solutions lie in proper organisation of communication and radar wavelengths, control of communications and separating the radar and communication aerials as much as possible.

47. Special filters are now being fitted to reduce the effect of local interference and to defeat the simpler forms of jamming. Another counter which can be tried with types 79 and 281 is to shift wavelengths slightly, but a shift of more than 2% will seriously reduce performance, and this reduction will have to be balanced against the seriousness of the interference or jamming. With types 79B and 281B, which have concentric cable instead of open wire feeders, a shift in wavelength should not be attempted as serious damage may result. In Carriers the fitting of both types 281B and 79B is in itself an insurance against one set being jammed. As stated, types 960M and P will be capable of rapid wave shift to counter jamming.

48. Again, WA sets are particularly susceptible to "Window" (*Chapter XV*) because of their wide beam and poor range discrimination. Some reduction in interference can be achieved by using the shortest pulse length, but this is not likely to help very much. The only solution may be to use the WS type 277 as suggested in *para. 45* (if it can be spared from surface warning).

Visual Lookout

49. The provision of radar does not reduce the necessity for maintaining a proper visual lookout. Radar still has many weaknesses, as described above, and accidents can happen in the best regulated circles. Thus while some eyes are glued to one sector, perhaps as a result of radar warning, care must be taken to keep a visual lookout in other sectors too.

50-53.

CONTROL OF AIRCRAFT WARNING RADAR

Aircraft direction room

54. Control of aircraft warning radar is exercised from the A.D.R., in immediate charge of which is the F.D.O.

55. From certain aspects the expression Aircraft Direction Room is an incomplete title, as its responsibilities are by no means limited to the direction of fighters or other aircraft. It cannot be too strongly emphasised that **the A.D.R. is responsible for knowing the air situation as a whole**, and for passing out information as follows:—

(a) To the Command—general air information, with particular reference to enemy aircraft which threaten the Fleet. A filtered air plot is kept in the Bridge Plotting Room, and may also be kept on the bridge. Alarm reports are, however, passed direct to the bridge and to other positions by loud speaker.

(b) To the Operations Room—information about own and enemy air reconnaissance, or friendly patrols.

(c) In Aircraft Carriers—to the Target Indication Room, through the Gunnery Liaison Officer if present—information about approaching enemy and friendly aircraft which may shortly be picked up by the Target Indication radar set. In other ships, where no separate Target Indication Room is fitted, the Target Indication personnel can themselves see the raids on the Main Aircraft Display Plot. In all cases liaison between the F.D.O. and T.I.O. must be highly developed, particularly if own fighters are following in enemy aircraft, when either the guns must be warned to withhold fire or the fighters must be called off by R/T. It is also necessary to keep the A.D.O. informed, either through the T.I.R. or direct, of the presence and identity of aircraft which may be sighted but which are outside the limited range (approximately 20,000 yards) of the present Target Indication Set type 293.

(d) To the Fleet, if ordered—Air warnings and notices.

56. In addition the A.D.R. contains the special radar displays and R/T equipment for directing fighters and other aircraft, *vide Chapter XI*.

Main display plot

57. The general air situation is shown on the Main Display Plot which is the nerve centre of air information, and it is from this position that immediate control of aircraft warning radar is exercised. The Plot is fed from:—

(a) Own WA set or sets, and the WS set (type 277) or special Heightfinding set (SM1 or SP) in order to receive information of low fliers when these sets are laid on the horizon.

(b) Other ships radar reports received by V/S, W/T or R/T.

(c) The Height Filtering Position.

(d) Y information including D/F bearings.

(e) Visual information.

58. The information is plotted as received on the back of the transparent surface. The Plot Officer has the duty of "filtering" the mass of information received, and marking in an estimated filtered track of each aircraft or group of aircraft as fully explained in *C.B. 04262 Part IV*. As remarked in *para. 38*, aircraft tracks will often appear tortuous owing to poor bearing accuracy, and will require smoothing out. Also there may be discontinuity as the aircraft passes through a gap in the vertical coverage diagram, or loses height and ceases to be detected at all.

59. The Plot Officer is immediately responsible for :—

- (a) Initiating filtered reports of aircraft tracks which are passed internally to the Interceptor Plots, the B.P.R. and the H.F.P. amongst other places.
- (b) Initiating similar reports for transmission by V/S, W/T or R/T to the Fleet, as laid down in orders. Brief, urgent reports are usually passed by R/T; detailed reports of raid tracks on the Radar Reporting wave, *vide Chapter XIX*.
- (c) If Controlling Ship, controlling radar guardships and other ships who may be passing in reports, *vide para. 62*.
- (d) Giving necessary orders to own radar sets, *vide para. 60*.

Control of own ship's radar

60. The plot is responsible for giving orders and/or information to each radar set in use for aircraft warning on the following points :—

- (a) Orders to commence operating or to cease operating.
- (b) Type and rate of sweep.

(i) As explained in *para. 9* continuous all-round sweep should normally be ordered. There is little object in sector sweeping, even against low fliers, provided type 277 or similar set is available. A possible exception occurs if type 277 is not available, when it may be advantageous to search for low fliers over a likely sector using type 281 or even a suitable gunnery radar set.

- (ii) The normal rates of sweep are :—

Type 281	...	...	2 r.p.m. (4 r.p.m. when conducting fighter interception).
Type 79	...	...	about 2 r.p.m.
Type 277	...	...	6 r.p.m.

As explained in *para. 6*, the effective sweep rate will be decreased if sets are required to stop for heightfinding or to classify echoes, or in the case of type 79 if ordered to watch too many targets simultaneously. The plot officer must bear these reactions constantly in mind, and the order to "hold" one target should rarely be given.

(iii) In order to maintain as fast a rate of sweep as possible, and generally speed up the reporting of important targets, it is a good plan to order that echoes of friendly aircraft (or those outside or inside a certain distance) are to be disregarded or reported only every third or fourth sweep. Similarly, it may well be unnecessary to receive continuous reports of our fighters whose course and speed are known, until they are getting close to the enemy. These remarks apply even if P.P.I. is used, since the operator cannot report the bearings and distances of numerous targets and efficiently watch for new echoes at the same time.

(c) *Information.* As much information as possible, e.g. about the movements of friendly aircraft, should be given to the operator in order that he may realise what is going on and appreciate which targets are the most important to report first.

(d) *Pulse length.* The normal pulse lengths are given in *para. 40*. When close to the land a shorter pulse length may be advantageous, *vide para. 44*.

(e) *Range Scale.* Normally the longest scale is used on WA sets (an exception being when close to land, *vide para. 44*). WS type 277 is normally operated on the 0-75,000 yards scale when used for surface warning, but when used for aircraft warning the 0-150,000-yard scale may be more suitable, if it is acceptable to the Operations Room.

61. A close liaison must be kept with the Operations Room as regards the use of WS type 277, remembering that this is primarily a tactical set*. If type 277 should be required for heightfinding or any other purpose which interferes with its surface sweep the concurrence of the operations room must first be obtained. Similarly, the Operations Room must keep the A.D.R. fully informed if they intend to use sector sweeping, since all round low cover will then be lost.

Control of other ships radar. (See also Chapter XIX)

62. When Controlling Ship, the Plot Officer also has the responsibility of controlling the sweeping of the guardships' radar, and controlling the radar reports from other ships. The principles in *para. 60 (b)* apply except that more targets can be watched without losing all-round cover, since there are more sets available. The following should be borne in mind :—

(a) At least one ship should be left as free as possible to keep an all-round watch, the duty of reporting particular raids being left to, or turned over to, other ships available and distributed amongst these ships as equally as possible.

(b) The number of targets or "raids" being reported by W/T or R/T should not be allowed to reach a level which causes serious time lag on the reporting wave. It may be necessary for own ship to watch a number of targets in order to avoid congestion.

(c) Apart from this, own ships radar should be used to keep a general all-round watch and check the accuracy of incoming reports, assigning an index correction to other ships if necessary in order to keep the plot relatively correct. If the controlling ship is a carrier, the radar will also be required to pay particular attention to own fighters and their targets.

* *Note.* These remarks do not apply in the case of carriers or other ships directing aircraft where type 277 is primarily a low cover air warning set and the WC (T.I.) set becomes the normal tactical set.

(d) Strict control of the Radar Reporting Wave must be exercised by means of the control signals provided (*F.S.B. Article 148a*). Some ships have a tendency to wait until they get a "look in" on the reporting wave, and then rattle off a stream of reports, many of which are by then stale. This must be checked.

(e) Reports must be kept as brief as possible, "supplementary information" being passed only every third or fourth report.

(f) The more complete knowledge possessed by the controlling ship must be used to correct other ships, e.g. to point out that two ships are reporting the same raid.

(g) The technical superiority of certain sets, and the proved operating efficiency of certain ships, must be borne in mind when assigning duties and weighing the value of reports.

63. The control of aircraft warning radar in a large fleet calls for much skill and judgment. The object is always to maintain an up-to-date plot of the air situation as a whole for the benefit of the fleet as well as own ship.

Alternative method of controlling and reporting

64. With the advent of modern radar and communication equipment a different system of controlling radar and reporting within a unit has been tried and may supersede present methods.

65. This system has been made possible because of :—

(a) The fitting of two WA sets and a high-powered WS set (e.g. type 277) in certain ships (e.g. Aircraft Carriers). This enables one ship to obtain complete air cover, providing all sets are kept sweeping.

(b) The development of automatically continuously rotating aerials and P.P.I. display (e.g. types 281BM and 277), and also sector displays for heightfinding (*vide Chapter XI*), which obviate the necessity for stopping the sweep in normal circumstances.

66. With the new system all sets are kept sweeping continuously. The controlling ship (sometimes called the "Reporting ship") gives a "running situation report" by R/T of all the tracks on her main aircraft display plot. Other ships only make reports if the Reporting ship appears to have missed a raid or if there is a difference in information about height, course or size.

67. Under this system the control of other ships' radar is, of course, less difficult, and indeed may not become necessary. Much signalling is also obviated.

68-72.

Radar Policy

73. *Paras. 59 to 62* are written on the assumption that free use of radar is permitted, and are subject to the "Radar Policy" in force, *vide Chapter XIX*, which contains also further particulars of the organisation for aircraft cover in a fleet.

Other points to watch

74. Other points that the plot officer should watch are :—

(a) *Jamming or Window*. If this is experienced, an impending attack should be suspected, and if necessary type 277 used to investigate, *vide para. 48*.

(b) *Land*. When near land it may be necessary to use type 277 as described in *para. 45*. Enemy aircraft frequently approach from the land (and even make use of valleys) to escape detection.

(c) *Disappearance of tracks*. The disappearance of an approaching unidentified track should be regarded with suspicion. It may, of course, be due to an aircraft entering a gap in the vertical coverage diagram. It may equally be due to the aircraft intentionally losing height with the object of avoiding detection and attaining surprise; in this case the aircraft should ultimately be picked up by type 277, if available.

Use of interrogators to track friendly aircraft

75. The Interrogator can frequently be used to track friendly aircraft by means of their I.F.F. response. Examples are :—

(a) Low A/S patrols who may be beneath the first lobe of the WA set.

(b) Reconnaissance aircraft over a U-boat, in which case the aircraft should have switched to a special I.F.F. Code (No. 4).

(c) Friendly fighters out of range of the WA set, or in a gap.

(d) When the Radar Policy permits the use of interrogators but not the use of WA sets.

76. The range accuracy obtained by this method should be sufficient, but the bearing may be up to 30° or more in error owing to the wide beam of the interrogator.

CHAPTER XI

USE OF RADAR FOR DIRECTION OF FIGHTERS OR OTHER AIRCRAFT

FIGHTER DIRECTION

1. Without radar and its counterpart—efficient R/T communication—it would be impossible to use fighters to defend the Fleet effectively against air attack, and Fleet operations would be severely handicapped. With an efficient fighter direction organisation, on the other hand, the fleet can defy air opposition and attain its objective even within the range of shore-based aircraft, as witness the Malta Convoys and many other operations.

2. The technique of fighter direction is contained in *C.B. 04262*, and it is unnecessary to recapitulate the details here. The object is to destroy or disorganise attacking planes before they reach the Fleet, or to destroy a reconnaissance plane before it can detect our Fleet by A.S.V. To do this it is necessary to effect interception outside visual distance, and preferably at 30 miles or more. This requires an accurate radar track of the enemy from a much greater distance which may be as great as 70 miles, in order that fighters may be placed in the most advantageous position from which to approach the enemy. In the final stages the fighters must be placed close enough to be able to pick up the enemy visually or by means of their own (A.I.) radar. This distance varies between 5 miles and 1 mile, according to the visibility or the capabilities of A.I. (*vide Chapter XVIII*).

3. Aircraft Warning sets and the A.D.R., as described in the previous Chapter, provide the foundation of the radar information required for fighter direction. There are, however, three important additional radar requirements.

(a) *Accuracy and discrimination of location*, in order to achieve the relative positioning required particularly for low visibility interception which may be expected to become a normal proceeding in future.

(b) *Radar displays* on which a continuous plan is shown and on which interceptions can be carried out direct, so cutting out time lag in "telling".

(c) *Accurate Height*. It is just as easy to miss the enemy through flying at the wrong height as it is to miss him in the horizontal plane.

TYPE OF RADAR SETS USED FOR FIGHTER DIRECTION

4. At present the WA sets and WS sets as described in *Chapter X* are the only ones which can be used for fighter direction. The location accuracy of WA sets is, however, insufficient for consistently successful low visibility interception, and the broad horizontal beam clutters up the display to an unacceptable degree if there is any air density. Further, some WA sets may have to slow down or even stop to obtain height, or classify targets, or read I.F.F. coding, thus interfering with continuous tracking (and plan display in the case of type 281). WS type 277 overcomes some of these defects but can only "see" a 6° cone at a time, and is in any case usually laid on the horizon.

5. For these reasons type 980 is being developed as a special fighter direction set for large Carriers and for Fighter Directing Ships. It will use the same transmitter as type 277, but the aerial will be larger and so shaped that continuous all round cover will, it is hoped, be given out to 70 miles with the required precision of location. The projected vertical coverage diagram for type 980 is shown in *Fig. 40*.

As an interim measure type SMM is being fitted in Fighter Directing Ships (L.S.F.); this set is a type SM1 (*see below*) modified by the substitution of a large aerial which gives plan display but not elevation. Both types 980 and SMM require stabilisation in order to preserve bearing accuracy and avoid distortion of the vertical coverage diagram if the ship rolls or pitches.

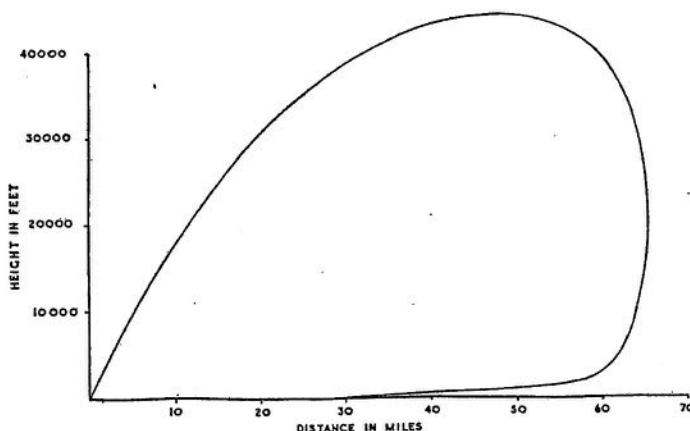


Fig. 40—Projected vertical coverage diagram for fighter direction set type 980.

6. U.S. type SM1 or SP, fitted in certain carriers, can be used to a limited extent as Fighter Direction Sets. In SM1 the aerial scans a vertical segment of 12° in steps of 3° (i.e. the beam width); any segment can thus be searched, e.g. $0-12^\circ$ or $8-20^\circ$ up to 75° and the relative position of the enemy and our fighters may thus be seen on P.P.I. if they are both within 12° of elevation. The primary function of these sets, however, is accurate heightfinding, and when so employed plan display has to be sacrificed. It is clear that separate plan-location and heightfinding sets are the ideal and this has led to our policy in developing type 980 (para. 5) and heightfinder type 981 (para. 51).

7. Large ships other than carriers will not be able to take types 980 and 981, and will have to continue to rely on the WA set and what help they can get from type 277 (or SP). Type 960M, if fitted will, however, be an improvement on type 281 because it will have a narrower horizontal beam.

8. Small ships cannot normally be fitted with an aircraft warning set larger than type 291 or SA. These sets, together with type 277, will provide limited fighter directing facilities.

RADAR DISPLAYS, AND LAYOUT IN THE A.D.R.

9. The air situation as a whole is shown on the Main Aircraft Display Plot in the A.D.R. The actual interceptions are normally carried out at one or more Interceptor Plots in a separate part of the A.D.R., fed by filtered information (position and height) from the Main Plot. Nowadays the Interceptor Plots are themselves radar displays, i.e. Skiatrons, and if the enemy and our fighters are being continuously detected their position can be plotted direct on the Skiatron surface so cutting out all time lag in reporting, filtering, and passing information from the Main Plot.

10. The Skiatron is normally operated from type 281, but arrangements are made so that type 277 can be used instead, if, for example low fliers are expected to be the target, or if the land echoes are likely to render the WA set useless. The change over takes half an hour, so it is necessary to forecast which set should be displayed. In future, of course, type 980 will always be displayed, where fitted.

11. The Skiatron must be kept set for best performance by adjusting the focus, brightness (marked "bias") and input controls as described for the P.P.I. in Chapter II. It is also necessary to avoid too intense "painting" which may burn permanent stains, particularly when using type 277. The danger of permanent staining when the aerial is stopped is obviated by an automatic device which switches off the display.

12. In conjunction with each Skiatron is fitted a P.P.I. which is normally operated from whichever set is not being displayed on the Skiatron. Thus a normal arrangement would be type 281 on Skiatron and type 277 on P.P.I. The object of the P.P.I. is to enable the F.D.O. to see at a glance the position of aircraft not at present showing on the Skiatron, e.g. because they are in a gap, or because they are too low for detection by the WA set. Alternatively, the P.P.I. can be used to effect interception, though this is not as accurate or easy as on Skiatron.

13. In some cases the P.P.I. can also be switched to the Target Indicating set type 293. The reason for providing this facility is that when fighters are patrolling nearly overhead, which is common, they are obscured by the ground wave of WA radar which may extend outwards and upwards up to 3 miles; under these circumstances they cannot therefore be plotted, and until they emerge from the ground wave cannot be given an accurate "vector" to intercept. Type 293, on the other hand, has a ground wave of only 200-400 yards, and "looks up" to an angle of some $50-60^\circ$, so that the exact position of our fighters will often be obtainable from this set.

Display of I.F.F.

14. It is clearly important that the F.D.O. should be able to tell at a glance which are our fighters, or a particular section of fighters, on the radar display. This requirement increases in importance with the air density. Unfortunately, as explained more fully in Chapter XIV, direct display on the Skiatron of the normal "A" band I.F.F. is not satisfactory, and it is at present necessary to stop the WA sets and Interrogator aeriels on the bearing of the target in order to obtain a response and associate it with the parent echo, and to read the I.F.F. code. This is because the I.F.F. can be triggered over a wide arc, and owing to its frequency sweep may not be triggered at the precise moment that the aerial whilst sweeping round is pointing at the target; so that the I.F.F. response may be in considerable error for bearing and therefore impossible to associate with the parent echo on the Skiatron. It can be appreciated that a number of such unrelated responses would soon confuse the interceptor plot completely.

15. To overcome this, fighters are, or will be, fitted with a modified I.F.F. known as Mark IIIG which, when ordered to be switched to "G-band," responds intermittently on a different and fixed wavelength. A special G-Band Interrogator type 941 will be fitted with types 281BM, 960 and 980 which will enable response from fighters to be shown on the Skiatron at will with sufficient bearing accuracy and without stopping the sweep.

16. At the same time a separately controlled Interrogator type 243Q will be provided which will obtain range and bearing of normal ("A Band") I.F.F. response from any friendly aircraft, whether fitted with I.F.F. Mark III or IIIG, and display it on a sector display panel L43.

17. The I.F.F. has 6 codes, 3 of which (numbers 2, 3 and 5) may be allocated to aircraft requiring special identification, as explained in Chapter XIV.

Summing up therefore :—

18. (a) "G-Band" response from fighters will be displayed on the P.P.I. or Skiatron direct when Interrogator type 941 is fitted.

(b) Normal "A-Band" response cannot be displayed on the Skiatron. At present the response and code must be obtained by stopping the WA set aerial, since the aerial of Interrogator type 243 is fitted to it. When a separate Interrogator type 243Q is fitted it will not be necessary to stop the WA set sweep.

(c) Two methods of radar recognition of fighters will eventually be available, namely by type 941 and I.F.F. Mark IIIG, and by type 243Q and the codes of I.F.F. Mark III.

19. Should recognition by radar methods fail, it may be necessary to resort to the expedient of ordering fighters to make an alteration of course so that they can be identified by their track.

20-24.

HEIGHTFINDING

25. The subject of radar heightfinding is dealt with in this chapter, since it is of most importance in Fighter Direction. It should be remembered, however, that the Gunnery Target Indication Organisation also requires height, as explained in *Chapter XII*.

26. At present it must be admitted that heightfinding is one of the weak links in Shipborne radar. It is a more difficult problem afloat than it is ashore where the platform is stable and there is no limit to the size and number of aerials.

27. The requirements for heightfinding accuracy are :—

(a) In the Warning Zone a rough but reliable indication of the height, say to 2,000 feet, so that the F.D.O. knows whether the fighters will have to be positioned high, medium, or low.

(b) As the Fighter Interception Zone is approached and entered, the requirement is for more accurate height, say to 1,000 feet. As the interception proceeds the requirement becomes more stringent and accuracy of 500 feet or less is desirable for some time before interception takes place. At this stage relative height (*i.e.* height difference between enemy and fighters) becomes more important than absolute accuracy.

28. At present requirement (a) can generally be met. Requirement (b) can sometimes be met given sufficient skill and practice, but cannot be relied on.

METHODS OF HEIGHTFINDING

29. There are two main methods of heightfinding used afloat :—

(a) By making use of the shape and varying intensities of the broad vertical coverage diagram of WA sets.

(b) By using a narrow beam set whose aerial is elevated till it is pointing at the target. This requires accurate stabilisation of the aerial in order to provide a horizon datum. Such sets are known as "Heightfinding Sets," or "Heightfinders," though strictly speaking they measure elevation.

30. The subject of heightfinding is dealt with very fully and clearly in the *Heightfinding Manual (C.B. 4224/44)* and is only summarised here to show its operational reaction.

WA set methods

31. Referring to the vertical coverage diagram of type 281 shown in *Chapter X, Fig. 37*, there are three methods by which the height can be estimated :—

(a) By the range at which an aircraft is *first detected*, *e.g.* enters the first lobe as at X1. This method is fairly reliable and often accurate to 2,000 ft. or better with metric (WA) sets. It fails if the aerial does not happen to be pointing in the right direction at the right time (when the reported height will be too low), or if the aircraft flies over the first lobe, as at Y. In the latter case it will not be detected till it enters the second lobe and the reported height will be greatly in error, in this case by 22,000 ft. (30,000 correct, 8,000 reported).

(b) By the points at which the aircraft enters gaps or *minima* in the coverage diagram, as at X5 to X6. These points give a check on the height which may be accurate to 500 ft., but again the aerial must be looking in the right direction to observe them.

(c) By the *rate of change of echo amplitude* as the aircraft traverses each beam. It will be recollected from *Chapter II, Fig. 7*, that the intensity of the beam is strongest at the centre. Consequently the echo at X2 will be stronger than X1, and a maximum will be reached at X3 after which, at X4, the echo amplitude will have decreased. The rate of change differs in each part of the lobe and can be related to the height.

32. In practice all three of these methods are used to deduce the best possible height estimation and to compete with the case of an aircraft changing height. If, for example, the aircraft in *Fig. 7* lost height from X1 to Z, this could be told from the rate of change of echo amplitude actually observed and from the fact that the first minima occurred at 35 miles, and not at 53 miles as expected.

Disadvantages of the WA set methods

33. The most obvious disadvantage of the WA set methods is that it is *at present* necessary to stop the sweep in order to measure echo heights accurately, thus interfering with reliable all round cover, and also with plan display in the case of type 281; though with skill and

practice fairly accurate measurement of echo height can be made with type 281 if the speed of rotation does not exceed 2 r.p.m. In order to avoid this drawback the intention is to fit sector display panels L43 with each WA set. The L43 has an after-glow tube and will enable echoes over selected 6° sectors of bearing to be kept under accurate observation without interfering with the sweep rate of either type 281 or 79.

34. Another snag of the WA method of heightfinding lies in the fact that ambiguity may arise, as explained in *para. 31*, through uncertainty as to which lobe the target is in. At close ranges, where there are many lobes and gaps, this drawback is accentuated. Type 79 is a better set than type 281 in this respect, since it has fewer lobes and gaps, and the first lobe is high and steep enough to rule out ambiguity at least between the first and second lobes.

35. Other disadvantages of using the vertical coverage diagram for heightfinding are:—

(a) The strength of echo differs with the size and number of aircraft, and with their aspect (*i.e.* inclination). This affects methods (a) and (b) of *para. 31*.

(b) Under conditions of anomalous propagation the lower part of the first lobe may be extended. This affects method (a), of *para. 31*, resulting in an over-estimation of height.

36. It will thus be seen that heightfinding by WA sets is an inexact science. It can, however, be made very much less inexact by constant practice with the co-operation of the A.D.R., and by careful calibration (*para. 40*). As the WA method is often the only one available, everything must be done to produce the best possible results.

Use of two WA sets

37. Where two WA sets are fitted, as in large carriers, it will be seen from *Chapter X, Fig. 37*, that their vertical coverage diagrams are complementary. The use of both sets simultaneously for heightfinding will therefore give added accuracy and, more important, should rule out ambiguity.

U.S. Sets

38. U.S. sets such as type SK are unreliable for heightfinding because when mounted at normal ship heights the wavelength used results in a large number of lobes and gaps, and the first lobe is low and lacks a steep front. This results in disadvantages similar to those of type 281, but more accentuated. Considerable skill is required to obtain heights with such sets. It may be asked why, if this is so, the U.S. Navy have had such success in shooting down Japanese aircraft. The answer appears to lie in the very good visibility, and the use of fighter patrols at several heights.

WC Sets

39. For the same reasons, heightfinding is practically impossible with type 291, and in addition, of course, the maximum range is small so there is less time in which to resolve ambiguity between lobes. U.S. type SA has a slightly longer range which gives more time to clear up ambiguity (or to get more confused).

CALIBRATION OF WA SETS FOR HEIGHTFINDING

40. The methods of heightfinding with WA sets depend upon knowing the shape of the vertical coverage diagram. Although this can be calculated approximately for a given aerial height, it will differ appreciably in practice, and it is imperative that the precise shape should be obtained by calibration. This consists in carrying out a number of opening and closing runs at different heights, as explained in *C.B. 4224/44*, in an area clear of land echoes. If the radar aerial is blanked over an arc, *e.g.* by the funnel or superstructure, it will be necessary to check the calibration on this bearing.

41. It is necessary to emphasise the importance of complete calibration at all heights. The poor heightfinding results obtained by and complained of by many Battleships and Cruisers are directly attributable to the fact that no complete vertical coverage diagram has ever been obtained; good results are impossible in such circumstances.

42. After initial calibration, check runs should be carried out whenever an opportunity arises, and a check is particularly necessary if a major component in the WA set has been changed. The interest and co-operation of the A.D.R. are necessary, *e.g.* in warning the radar office when an opportunity is about to occur and in passing other ships' height estimations for comparison.

43. Attention is also drawn to the necessity for range calibration (*Chapter X, para. 36*). An error of several miles arising subsequent to height calibration will upset the position of minima and render the vertical coverage diagram misleading.

SPECIAL HEIGHTFINDING SETS

44. The other method of heightfinding, which has been made possible by the development of high-powered centimetric radar, is to use a narrow beam and measure elevation by pointing the beam at the target. This, of course, requires very accurate stabilisation of the radar aerial in order to provide a horizon datum which will remain accurate under all conditions of roll, pitch and yaw.

45. The advantage of a special heightfinding set is that it allows the WA set or sets (and the special Fighter Direction Plan Display set) to carry on their proper function of all-round sweep. Furthermore, height ambiguity, to which WA sets are prone, can no longer rear its ugly head; while difference in target size and the presence of anomalous conditions do not affect accuracy.

46. On the other hand the range of special heightfinding sets is not yet great enough to be able to dispense with the use of WA sets at long range (*i.e.* at first detection). Also, only a limited number of raids can be dealt with simultaneously.

U.S. Types SM1 and SP

47. U.S. Type SM1 which is primarily a heightfinding set, uses a method of conical scanning which has the same effect as simultaneous beam-switching for bearing and elevation. A meter display is used to balance the echoes and obtain accuracy of elevation. Under normal conditions the accuracy should be 500 feet at 25 miles and 1,000 feet at 50 miles. Aircraft can be followed to greater distances, if they are sufficiently high, but the strength of echo will not usually be sufficient for accurate heightfinding. Heightfinding is not practicable below about $2\frac{1}{2}^\circ$ ($\approx 15,000$ feet at 50 miles) as the sea reflection then interferes with the beam pattern. As SM1 can carry out a vertical segment sweep, as described in *para. 6*, it should be unnecessary to have to use the WA set to put SM1 on to a target, in spite of the narrow beam.

48. U.S. Type SP is generally similar to SM1, ranges being slightly greater but elevation accuracy slightly less.

W.S. Type 277. Height Position Indicator.

49. Though type 277 is primarily a WS set it has rough elevation finding facilities up to 40° when fitted in large ships, and may often prove useful to obtain elevation or at least to clear up ambiguity of height from WA sets. The comparatively small range obtainable—25 miles—limits its operational usefulness for fighter direction. Accuracy above $3\frac{1}{2}^\circ$ should be $\frac{1}{2}^\circ$ which represents 1,200–2,500 feet at 25 miles. Below $3\frac{1}{2}^\circ$ ($\approx 9,000$ feet at 25 miles) heightfinding is not practicable owing to sea reflection.

50. Owing to the narrow beam and absence of conical scanning it will usually be necessary to put type 277 on the correct bearing from a WA set. To facilitate this azimuthators are being fitted; by training the type 277 aerial the operator rotates a bearing cursor fitted to the WA set P.P.I., placed near him, and by bisecting the echo on the WA set display puts type 277 on for training. Type 277 then sweeps in elevation and echoes are displayed on a **Height Position Indicator (H.P.I.)**. This is similar to a P.P.I., except that the radial trace represents elevation instead of bearing. In order to give greater accuracy of reading off, movement of the radial trace is multiplied by 4, *i.e.* it appears at an angle of 80° when the elevation is 20° . This spreads out the echo, which is bisected by eye and elevation is read off. Since the range of the echo is also measured, curves on the face of the H.P.I. give direct reading of height. The H.P.I. is illustrated in *Fig. 41*, and may also be seen on the left side of the type 277 office illustrated in *Photograph 76*.

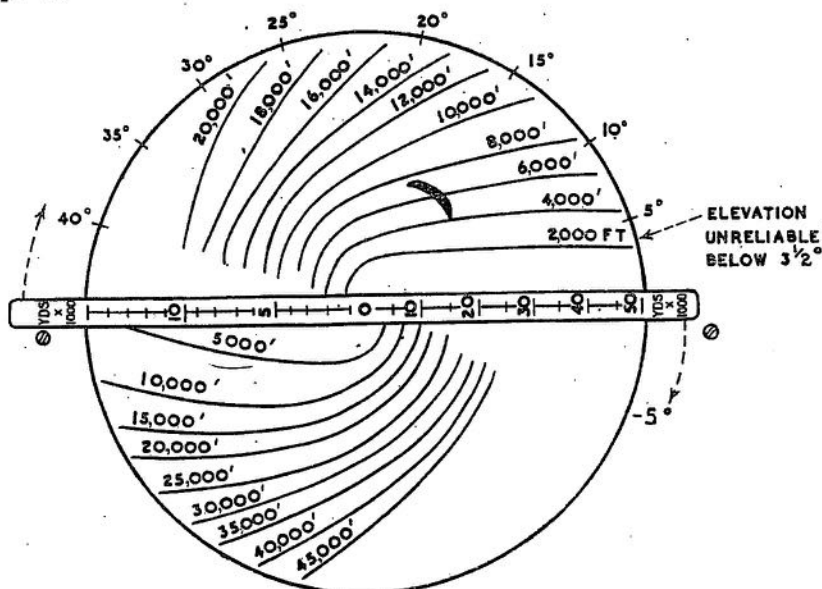


Fig. 41—Standard Height Position Indicator (H.P.I.) display as used with type 277, showing elevation scale, height curves, and the cursor with two range scales. A typical echo is shown; its width is four times that which would appear on P.P.I. because the elevation scale is expanded so as to achieve greater accuracy.

Type 981.

51. Type 981 is under development as a special heightfinding set to work in conjunction with the Fighter Direction Plan Display set type 980 in Carriers, and Fighter Directing Ships.

Calibration of special heightfinding sets

52. As with WA sets, calibration is necessary to obtain any elevation index correction and to ascertain the precise elevation below which heightfinding is unreliable. Only a few runs will be needed.

HEIGHT FILTERING ORGANISATION. THE H.F.P.

53. From what has been said it will be seen that there may be a mass of information on heightfinding, particularly in carriers with two WA sets and a heightfinding set or type 277, but that no one source is likely to provide a complete, timely, and unambiguous answer. Clearly all available evidence must be pieced together in one position, and the "filtered" result passed to those who require it in the A.D.R. (for fighter interception) and the T.I.R. (for blind gunfire).

54. All height information is therefore passed to the **Height Filtering Position** which ideally contains:—

(a) P.P.I. and Sector Display Panels L43 from the WA set or sets. L43 enables the echo heights on selected 6° sectors to be kept under continual accurate observation without stopping the sweep of the WA set or sets.

(b) Vertical coverage diagrams for the WA set or sets.

(c) P.P.I. and H.P.I. display and remote control of the Heightfinding set or type 277. (Note. Remote control of type 277 training and elevation is under development.)

(d) A filtered air plot, fed from the Main Display Plot in the A.D.R. This is necessary in order to follow the air situation and enable raids for which height is required to be picked out easily and referred to by Raid letter instead of bearing and distance.

55. The H.F.P. will ultimately form part of the R.D.R. In the meanwhile it may be located in one of a number of alternative positions, depending on the space available, e.g. type 277 office, a WA set office, or a separate office. Of these the type 277 office is best until remote control of type 277 becomes available.

56. The H.F.P. is manned by R.P. ratings, a higher rating specially trained in height-finding being in charge. The Radar Officer will often take charge temporarily, or supervise, but should not himself assume the duty of permanent heightfinder as his duties and responsibilities have a much wider scope.

57-59.

DIRECTION OF AIRCRAFT OTHER THAN FIGHTERS

60. The functions of the A.D.R. and F.D. Organisation are likely to be extended to cover the radar direction of aircraft other than fighters. Examples which have occurred, or could be visualised are:—

(a) Directing an A/S escort aircraft on to a U-boat which has been sighted or detected by a ship of the screen.

(b) Assisting sections of an attacking force to rendezvous, or return to base.

(c) Directing an attacking force towards a reconnaissance aircraft over an enemy surface unit. In this case the reconnaissance aircraft will be distinguishable by the use of I.F.F. Code 4.

61. In order to introduce the geographical element which is desirable in some of the above situations it is under consideration to combine a Skiatron with an A.R.L. plot, the result being known as an "auto-radar plot."

CHAPTER XII

USE OF RADAR FOR GUNNERY

1. This chapter gives only a general description of the use of radar for gunnery fire control and target indication. A full description of the use of each type of set and of the many applications of radar to gunnery is contained in the C.B. 4112 series, while the effect of radar on gunnery control and spotting procedures is dealt with in the "Firing Manual," C.B. 3120, and the H.A. Firing Manual C.B. 3001.

2. Radar now permeates gunnery fire control. Whereas in its early days radar was 'added on' to the gunnery organisation, it is now incorporated in all fire control equipment in the earliest stage of design.

3. In order to appreciate what radar has done for fire control, it is easiest to recall the deficiencies of fire control in pre-radar days:—

- (a) The range was often inaccurate, particularly at long ranges. Range taking was much affected by atmospheric conditions and depended a lot on the individual range-taker.
- (b) Range was consequently inconsistent, *i.e.* an irregular "rate plot" was the rule rather than the exception.
- (c) Range-taking in bad visibility was difficult and at night impossible without illuminants (searchlight or starshell) and the use of these may be embarrassing.
- (d) In the dark no accurate line of sight for bearing was available.
- (e) There was little warning of the approach of targets, and consequently guns could not all be trained on the correct look-out bearing.
- (f) Without the aid of spotting aircraft, spotting for range was not possible on salvos which were not exactly in line, and in poor visibility was difficult even when in line.
- (g) The absence of continuous and accurate ranges precluded any form of forecasting the enemy's movements during time of flight.

4. Radar can effectively overcome these deficiencies as follows:—

- (a) Except against very low or very high aircraft ample warning is given.
- (b) Ranging is available in any visibility to a range and accuracy which exceeds that of the gun. The radar range error, if any, is a constant and is no greater at long range than at short range; and it is little affected by weather or the human factor.
- (c) In the dark a line of sight is available which in modern sets is nearly as accurate as visual. In the latest anti-aircraft sets a line of sight for elevation is also given.
- (d) As a result of (b) and (c) accurate and smooth rate of change of range and bearing can be obtained.
- (e) Fall of salvos which are in line or nearly in line can be spotted by radar at ranges much greater than those of "old-fashioned" night actions of former days, and this can be done in any visibility.
- (f) By making continuous accurate ranging available, forecasting of the enemy's movements during the time of flight becomes possible.

5. The net result of all this is that *by day* fire is much more accurate, and there is no reason why all salvos (including the first) should not be exceedingly close to the target even if they do not straddle. By night (or if the enemy uses a smoke screen by day) actions can be fought at ranges which approach those of day action ("Duke of York" engaged "Scharnhorst" up to 20,000 yards, which was the limit of her splash spotting range with her GS type 284 under the prevailing weather conditions). Naturally, the accuracy by night is not quite what it is by day, since radar line of sight is not yet as good as visual; but that it can be effective at long range has been proved in many British and American actions.

6. Of course the advantage given to us over the enemy by radar assumes

- (a) That we have better radar. This is so at present.
- (b) That we are using it to the best advantage.
- (c) That the enemy does not take efficient radio countermeasures such as jamming or the use of window (*see Chapter XV*). This is a struggle which may develop at any time, and will be similar to the race between the gun and armour (only in this case the reply is to improve anti-jamming methods).

7. As regards (a) and (b), a warning is necessary: inferior radar well used is better than first-class radar misused. This means that continuous radar training is of the greatest importance.

SPECIAL REQUIREMENTS FOR GUNNERY RADAR SETS

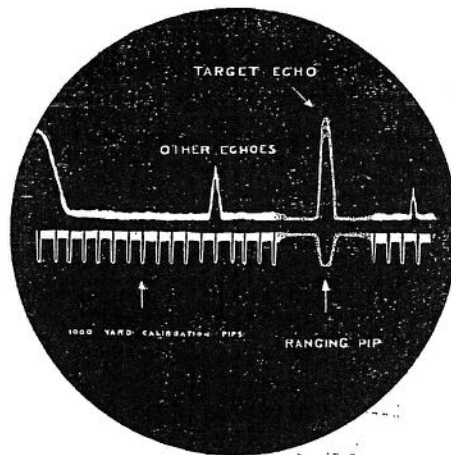
8. Subject always to being able to get sufficient range (which in these days presents little difficulty), the special technical requirements for gunnery radar are:—

- (a) Accurate and constant range.
- (b) Good range discrimination.
- (c) Accurate bearing.
- (d) Good bearing discrimination.
- (e) Accurate elevation in the case of anti-aircraft sets.
- (f) The ability to spot for range and line up to the maximum range of the gun.

Requirements (c), (d) and (e) call for a set with a narrow beam. Unfortunately, making the beam narrow in a set whose aerial is fixed to a director and therefore cannot sweep fast, makes it more difficult to search for and pick up the target; this has led to the necessity for a separate Target Indication Radar set and organisation, *vide para. 77*.

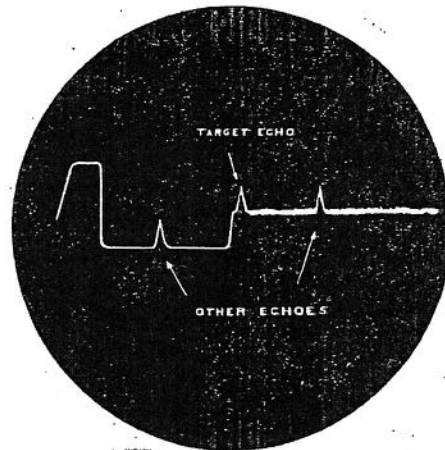
Range accuracy

9. Very accurate range is achieved by taking the particular part of the radar range trace in which the control is interested and "expanding" it electrically. This can be compared to using a sort of electrical magnifying glass. Fig. 42 shows some typical expanded traces, and it will be seen that in the case of L17/18, the trace is expanded for 1,000 yards either side of the target echo. In all expanded traces the leading edge of the target echo is aligned with some definite mark such as a "strobe" or the edge of a dip on the trace. Turning the handle to bring the echo into the right position also automatically transmits the range away to the fire control table (or wherever it is required). This cuts out time lag and therefore increases accuracy.



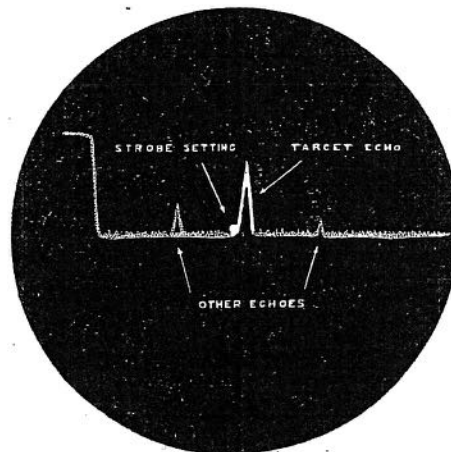
(a)
PANEL L17/18

(a) Used with GS sets, showing trace expanded 1,000 yards either side of target echo.



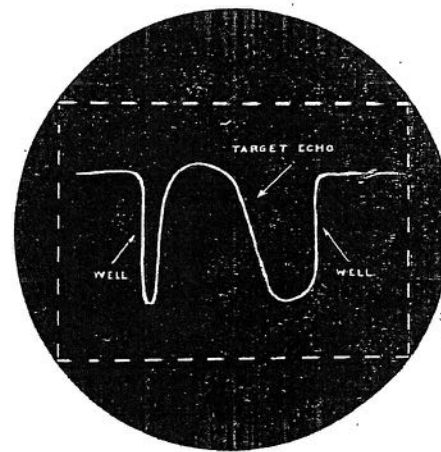
(b)
PANEL L22

(b) Used with GA, GB, and GC sets, showing dip or "step" in trace against which the leading edge of the target echo is aligned.



(c)
PANEL L20

(c) Used with WSR sets, showing bright spot or "strobe" which is aligned with the leading edge of the target echo.



(d)
PANEL L24

(d) Used with GA and GS sets. The "well" in the trace of L24 is being abandoned in favour of a dark spot or break in the trace, equivalent to a "strobe."

Fig. 42—Expanded traces used for accurate ranging.

Range discrimination

10. By this is meant the ability to distinguish between (and if necessary range on) two or more targets close together on or near the same bearing. Good range discrimination is essential for effective radar splash spotting, and is also necessary if there are several ships in the enemy's line and it is required to fire at one who is not the nearest. Range discrimination is achieved by using a very short pulse length; unfortunately, this affects the maximum range obtainable, so there is a practical limit to what can be done in this direction.

Bearing accuracy

11. This is achieved in gunnery sets by Beam Switching, as explained in *Chapter II*. Should the beam-switch break down, arrangements are provided to "centralise" the beam, but accurate bearing and blind fire by radar are not then practicable; and the radar reverts to the status of an accurate rangefinder.

Bearing discrimination

12. By this is meant the ability to distinguish between and take individual bearings of two targets whose range is the same or nearly the same, *i.e.*, does not differ by more than the range discrimination distance. Good bearing discrimination calls for a narrow beam in order that echoes not on or near the target's bearing may not be seen at all.

EFFECT OF BEARING DISCRIMINATION AND RANGE DISCRIMINATION ON GUNNERY TACTICS

13. The extent of the bearing and range discrimination of radar sets has a considerable effect on tactics as it concerns gunnery, and warrants careful study.

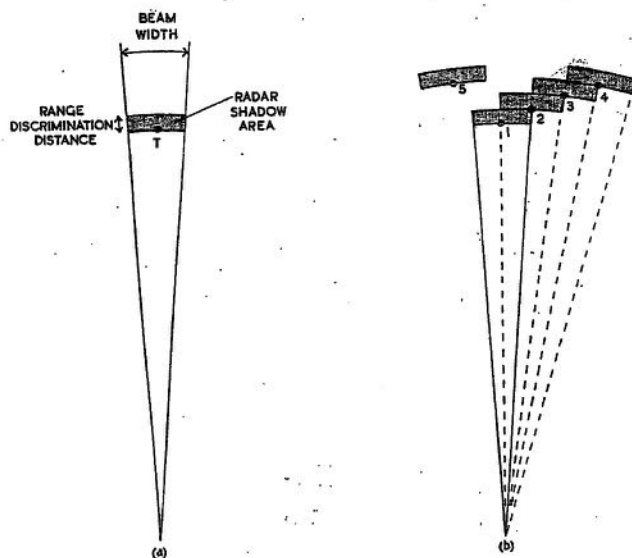


Fig. 43—Effect of radar shadow areas on targets close together. Fig. 43 (a) shows the radar shadow area cast around a target T on account of the beam width and range discrimination distance (*i.e.* the pulse length). Fig. 43 (b) shows targets (1 to 4) whose radar shadow areas just overlap. The targets cannot, therefore, be separated out. Target 5 can, however, be distinguished from the others since it is separated from any other target by an amount greater than the bearing discrimination and range discrimination. The above figures assume a search with a warning set using "A" display. If P.P.I. is used the angular separation to obtain discrimination must be approximately twice as great, as explained in *Chapter VII*.

14. The subject is discussed in *Chapter VII* and at greater length in Chapter IV of C.B. 4112 (1). Briefly, when the radar set is trained on a target the combined effect of the width of the radar beam and the length of the radar pulse causes a "radar shadow area" (Fig. 43 (a)) within which the echo from a second target will be swamped by that of the first, *i.e.*, discrimination between the two targets is not possible. The second target will therefore not be seen. In fact it is possible for several targets suitably positioned, as in Fig. 43 (b), to be indistinguishable on account of their echoes merging as the radar beam is trained. It is only fair to add, however, that the exceptional depth and width of echo of the supposed single target should give a clue to the fact that there is really more than one. It should also be noted that target No. 5, not being in the Shadow Area caused by any other target, will be distinguished separately.

15. Although the bearing and range discrimination of gunnery sets (and particularly GS sets) is intentionally made as good as possible, the "Shadow Area" may prove embarrassing. It can also be made to be embarrassing for the enemy if he is approached on a line of bearing, rather than in line ahead. This is made clear from *Fig. 33 of Chapter VII*.

16. For the same reasons, the radar beam casts a shadow area around the edge of land provided it is high enough to give a good reflection, and targets lying within this blind area cannot be ranged on, nor can bearings be taken by radar. It should be noted that this shadow area will be worst when approaching the land obliquely, and least when approaching it at right angles. Thus in *Fig. 44* the target X could be ranged on by B, but not by A. The moral is obvious.

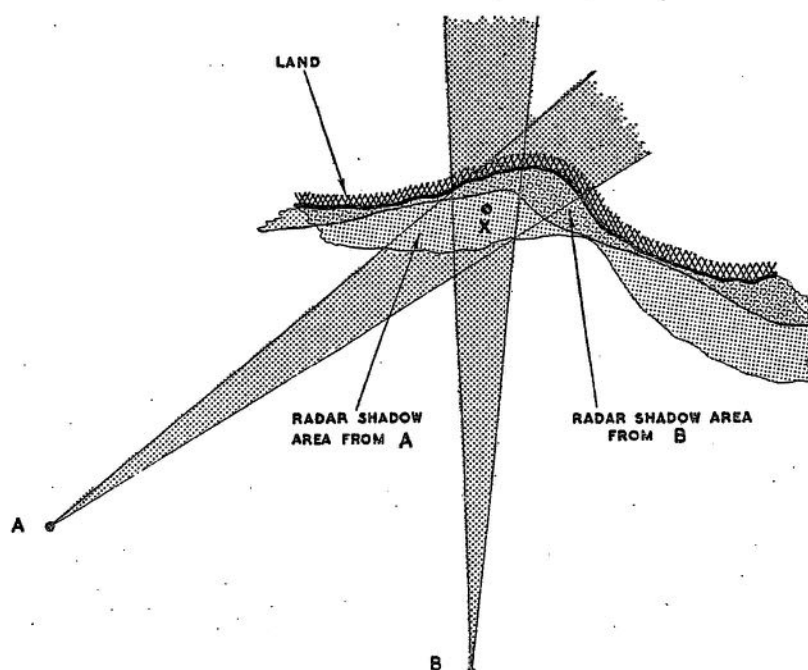


Fig. 44—Showing the effect of radar shadow area near land as seen from two positions A and B. From the former the Coast is viewed obliquely; from the latter it is viewed at right angles. Target X can be detected from B, but not from A. (For the method of constructing the shadow area see Chapter VII, Fig. 28.)

17. The above remarks apply to surface targets. For aircraft targets a third dimension is introduced, and the width of the vertical beam of the GA (or GC) set will determine the size of the space within in which two targets cannot be separated out. Similarly, too, if the aircraft is approaching over land, it may be obscured by the vertical shadow area caused by detection of the land. The very wide vertical beam ($\pm 22^\circ$) of GA type 285 will clearly cause great difficulty in these circumstances compared to type 275 whose vertical beam is only $\pm 6^\circ$.

18. Warning radar sets in general have wider beams and longer pulse lengths than gunnery sets, and therefore cause larger shadow areas, particularly when displaying on P.P.I. The gunnery sets must therefore be used to obtain discrimination and to separate out targets.

Snags of beam-switching

19. Beam switching is fitted to improve bearing accuracy, but by splitting the beams and setting them out at an angle the total coverage is increased by about 50%. Bearing discrimination is thus reduced, and the shadow area increased in proportion.

20. Another snag about beam switching is that when there are two targets within the total coverage diagram it is difficult and sometimes impossible to get an accurate bearing of either. The reason for this can be seen from *Fig. 45*. When pointing at target A (*Fig. 45 (a)*) equal echoes will be received from either beam. If a second target B at the same range as A approaches as shown, an echo of B will be received from the right-hand beam, but not from the left-hand beam.

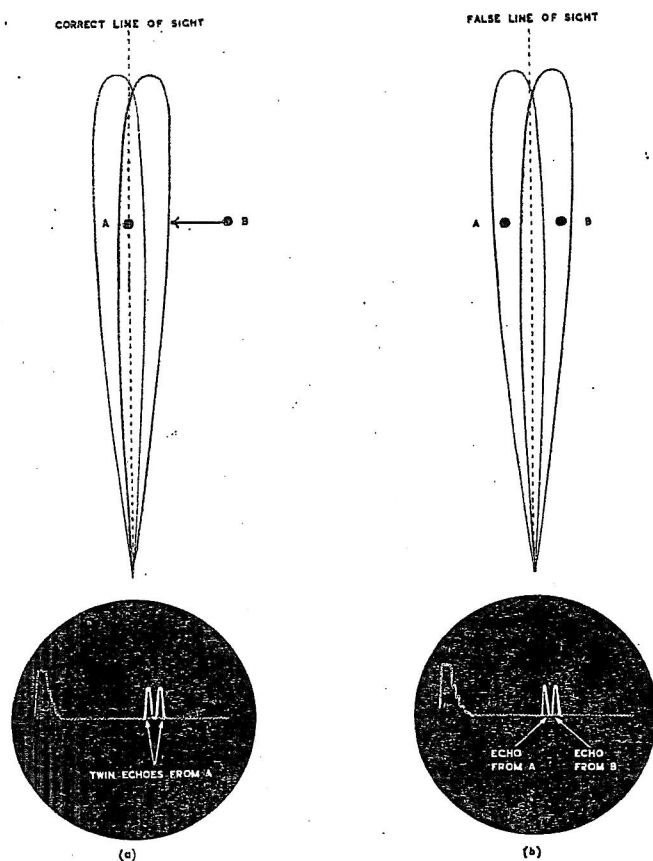


Fig. 45—Effect on beam-switching if two targets are close together. For explanation, see paras. 20–21.

21. The echo from B will reinforce the right-hand echo from A, and two unequal echoes will therefore appear on the bearing tube. The radar operator, little suspecting, will train right to equalise the echoes and will in fact come to rest *between* the targets, as shown in *Fig. 45 (b)*. Not only will the bearing be false, but there will have been no indication of the fact.

22. Of course this trouble will only occur if the second target enters the radar blind area of the first, or is there originally, but when it does occur the result may be serious. A skilled operator can sometimes sort matters out by training right and left. As this is done three pairs of echoes may be observed: to left and right two pairs of large echoes (on the true bearings of A and B), and between them one pair of smaller echoes (on the false bearing). The false bearing echoes are smaller because the targets are then on the edge of each beam, and they may also be distinguished by the fact that training right or left *decreases* the height of the right-hand or left-hand echo instead of increasing it.

23. Land to one side of the target and within the coverage of one beam will also have the effect of “pulling” the apparent bearing to right or left, while at close ranges the effect of side lobes is to cause additional confusion. It should be added that this limitation of beam-switching is considerably less pronounced with GS type 274 than with type 284, owing to the narrower beam of the former set.

LOW ANGLE GUNNERY RADAR

24. The problem is illustrated in Fig. 46 below:—

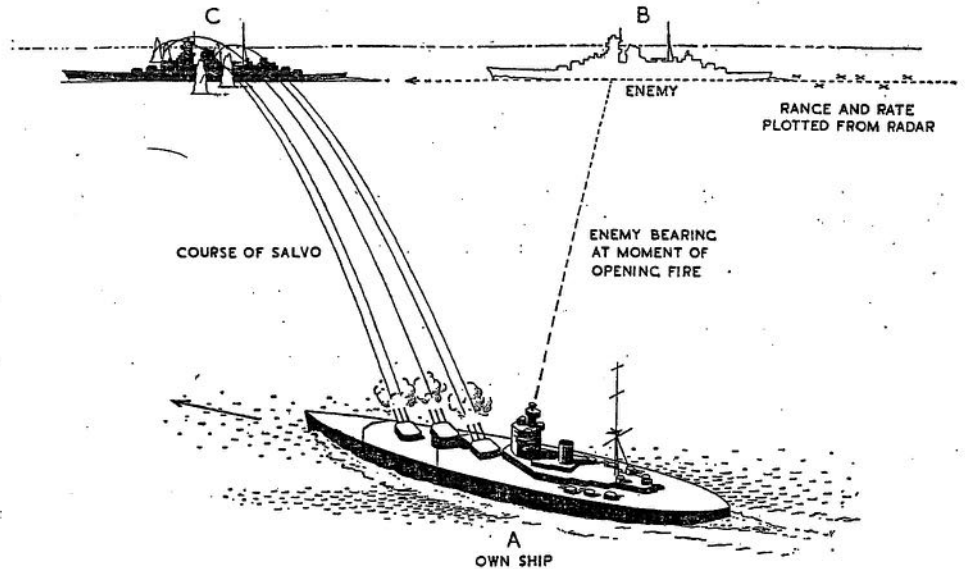


Fig. 46—The L.A. gunnery Control problem. Using the track of the enemy plotted by radar up to the point B, it is necessary to forecast the position (C) in which the Salvo, fired from position A, must fall in order to hit the enemy.

The course of the enemy will have been plotted either by radar range and bearing, or (preferably) by radar range and visual bearing. This gives his rate of change of range and bearing and—assuming that he continues on the same course and speed—and taking into account own ship's velocity and the effect of wind and ballistics, enables the salvo to be fired at the right range and in the right direction to coincide with his arrival at C.

25. The radar range having been corrected to allow for enemy's movement during the time of flight, own ship's velocity, wind and ballistics, has of course to be converted into elevation of the director and gun, and to make use of this it is necessary to have a horizontal datum.

In good visibility the horizon or the target can be used, but for blind radar fire the horizontal datum must be provided by other means, e.g., gyro or bubble.

26. Another important point is that the radar range as read off and after applying any index correction, gives the precise geometrical range of the target. This, however, is not necessarily what is required for the gun, because the gun does not always behave exactly as the ballistic range tables say it should (or alternatively the range tables themselves may not be quite right). What the gunnery officer wants to know is the difference between radar range and hitting gun range, i.e., the "straddle correction" to be applied to radar range in order to achieve a hit. The straddle correction has to be obtained by **calibration** at sea, by firing a series of salvos at known radar range and observing the fall of shot as described in C.B. 3120(1) Chapter III.

27. However, even if calibration of guns to radar has been carefully done, it is too much to expect that every salvo will fall correctly; for example, meteorological data may be inaccurate or the estimation of enemy's course and speed may be in error. So the necessity for spotting remains, and here radar is able to help again as echoes are received from the splashes up to considerable ranges. Splash spotting is best with centimetric sets (e.g., type 274), while with 50 cm. sets (e.g., type 284) the performance is being improved by the introduction of "Brads" (a large number of small dipoles) into the ballistic cap of the shell.

28. Radar splash spotting is, however, far from easy, and requires a special radar spotter with experience. The difficulties are as follows:—

- (a) Because the echoes are only fleeting, the operator tends to range on the peak of the echo and not the leading edge. This causes over-estimation of range.
- (b) Splash echoes will "swamp" each other if the distance between shots is less than the range discrimination distance.
- (c) Splash echoes of an "Over" or "Straddle" may be "blanked" by the target itself, and will in any case be "swamped" if they are less than the range discrimination distance beyond the target.
- (d) Ricochets may give echoes as big as those from the proper splashes.

Experience to date seems to indicate that it is better to range on the nearest splash echo and add half the normal spread, rather than attempt to estimate the "Mean Point of Impact" by ranging on each splash individually. This conclusion, however, may be altered after experience with type 274.

TYPES OF RADAR USED FOR LOW ANGLE GUNNERY

(Typical layouts are illustrated in *Figs. 47 to 55*. Aerials are also illustrated in *Photographs of Group I*)

GS sets

29. In large ships a special GS set is fitted. In future two GS sets will be fitted in Battleships and large Cruisers, one forward and one aft, in order to provide for divided control and in some cases to allow for blanked arcs or breakdown of one set. In small Cruisers, the after GA set will carry out the function of the second GS set when required.

30. **Type 284** (*Fig. 47*) has been the standard GS radar set. Formerly (type 284M) the ranging was done in the radar office, the result being passed by R.T.U. to the T.S. In type 284P, however, the accurate ranging panels and spotting tube are situated in the T.S. itself, as is also the remote training tube with its display of beam-switched echoes. So all necessary radar information is under the direct observation and control of the T.S. officer. A remote training tube is, however, fitted in the D.C.T. as well, principally in order to get the best accuracy of bearing at the moment of firing.

31. With type 284 arrangements can also be made to use the accurate ranging panel L18 (part of type 272P/273QR) in the T.S. This panel gives better accuracy than could be obtained by type 284M alone, and is a useful standby for type 284M or 284P.

32. **Type 274** (*Fig. 48*) is the successor to type 284 and is an improvement in every respect, *i.e.*, maximum range, range accuracy, and discrimination, bearing accuracy and discrimination, and ability to spot fall of shot. These advantages have been achieved by the use of a shorter wavelength (10 cms.) with a narrow beam and short pulse length.

33. The remote ranging and training tubes are fitted in the T.S. A special spotting tube is also provided, so that the same operator does not have to try to spot and range simultaneously. A remote training meter is fitted in the D.C.T.

34. Splash spotting can be carried out at greater range and with better discrimination than with type 284. In addition line spotting is possible to the extent that it can be seen whether shots are falling left or right, provided that they are within the beam. The actual extent of the error cannot, however, be measured accurately.

Summary of performance of types 284 and 274

35. The following is a summary of the performance of types 284 and 274. For further details see *Chapter III* and *Appendix I*.

Type	RELIABLE RANGE			RANGE ACCURACY	RANGE DISCRIM- INATION	BEARING ACCURACY	BEARING DISCRIM- INATION
	Battleship- Battleship	Battleship- Destroyer	Shell- Splashes				
284	30,000 yds.	18,000 yds.	20,000 yds. (15")	25 yds. (284P)	200 yds.	5-10'	6°*
274	42,000 yds.	38,000 yds.	25,000 yds. plus (14" A.P.C.) 35,000 yds. (14" K set non-delay)	15 yds.	100 yds.	3-5'	1½°

* With aerial ASF; with aerial ASG it is 10°.

GA sets

36. In small ships such as Destroyers where only one long range gunnery set is fitted the GA set carries out the function of the GS set in larger ships.

37. **Type 285** has been the standard GA set. As with type 284 the range was formerly read in the radar office (type 285M) but in later modifications (types 285P and Q) the accurate ranging panel, with a separate spotting tube, is in the T.S.

38. **Type 275** will replace type 285 in ships with Mark 6 or U.S. Mark 37 directors and the improvement will correspond with that of type 274 over 284 (*vide para. 32*) except that the beam is wider because it is primarily an anti-aircraft radar set.

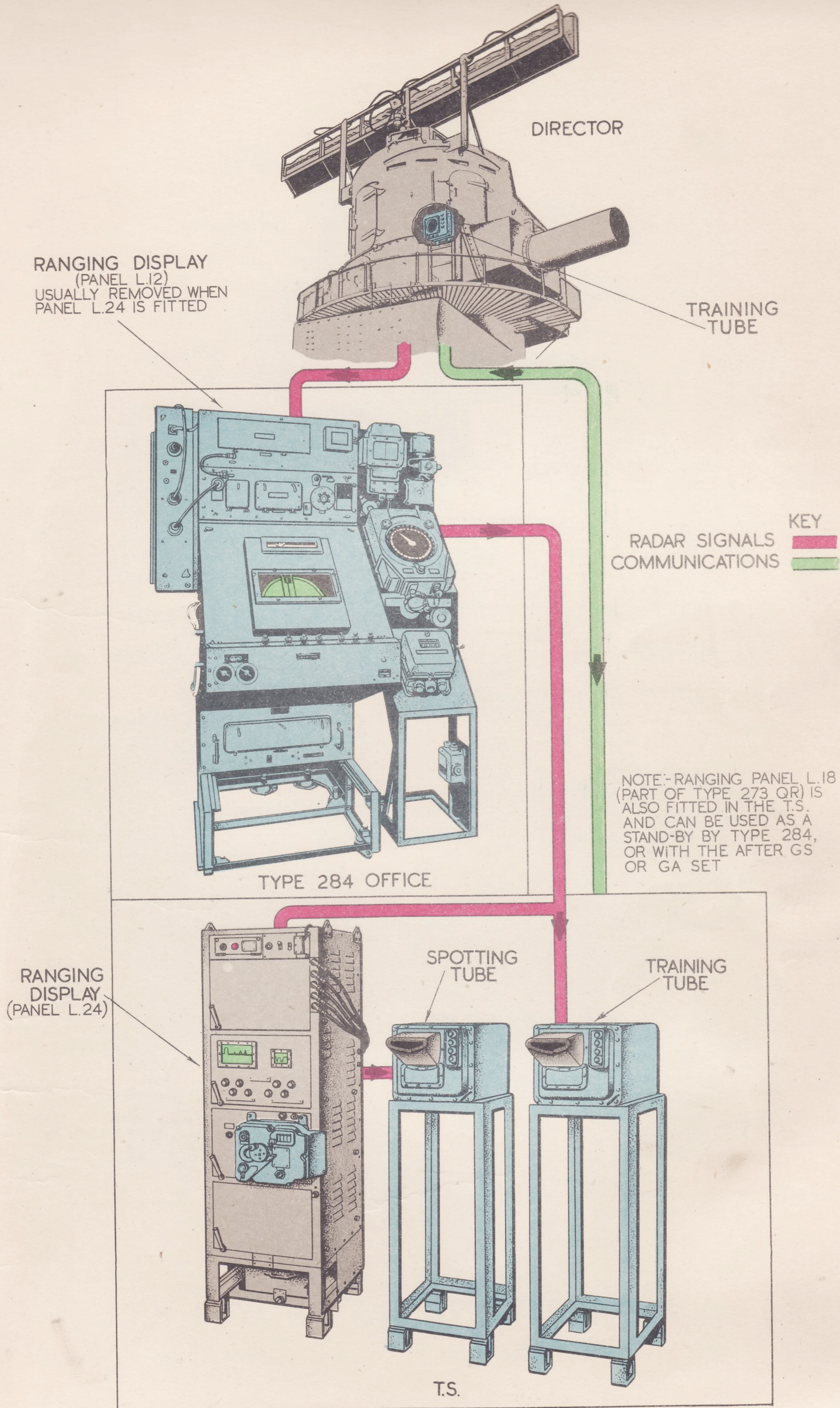


Fig. 47

LAYOUT OF GS TYPE 284

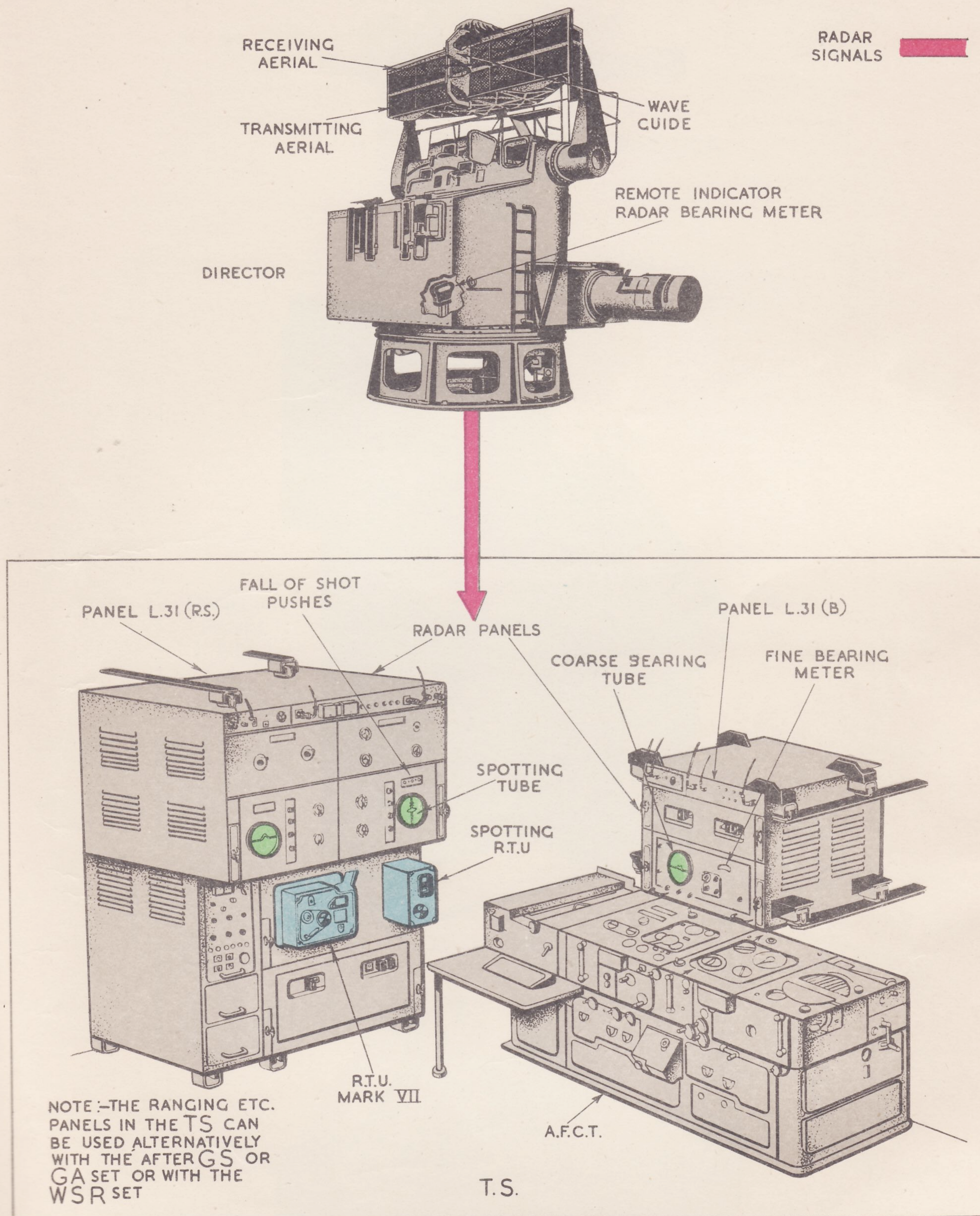


Fig. 48

LAYOUT OF GS TYPE 274

It will be noted that in this set all the Radar panels are in the T.S.

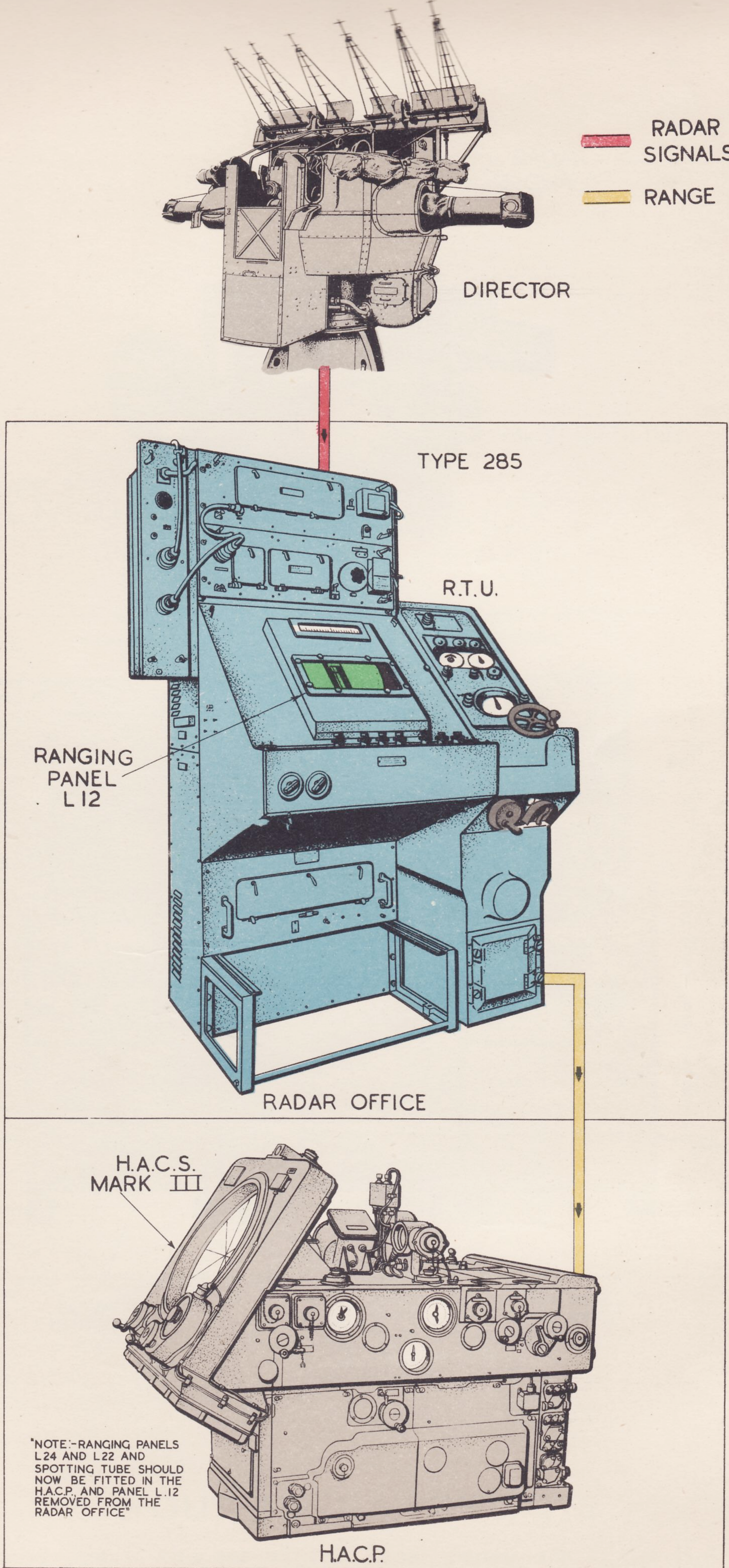


Fig. 49
LAYOUT OF GA TYPE 285

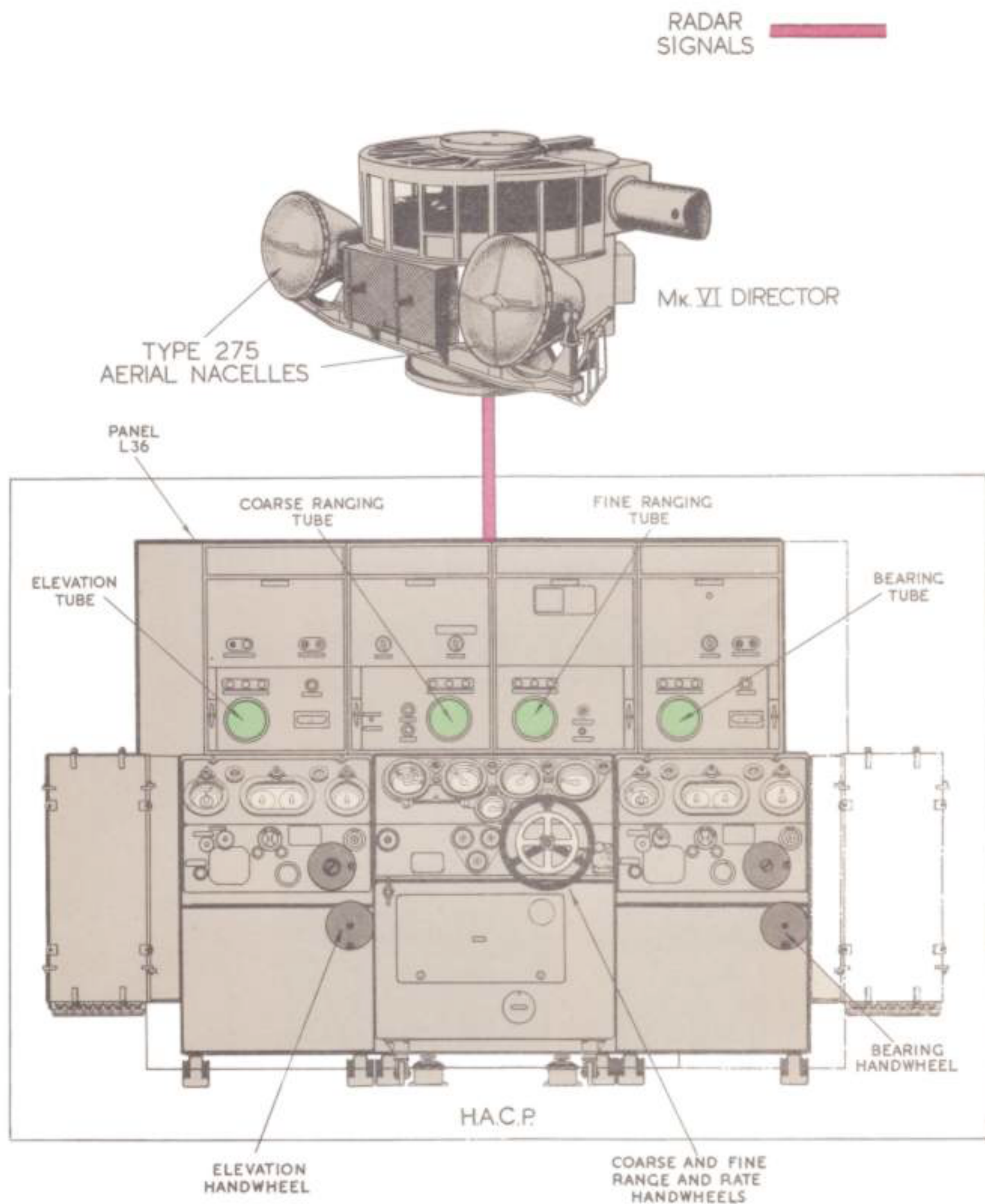


Fig. 50

LAYOUT OF GA TYPE 275

It will be noted that in this set all the Radar panels are in the H.A.C.P. (or T.S. in destroyers). The fire control tables, etc., are not shown

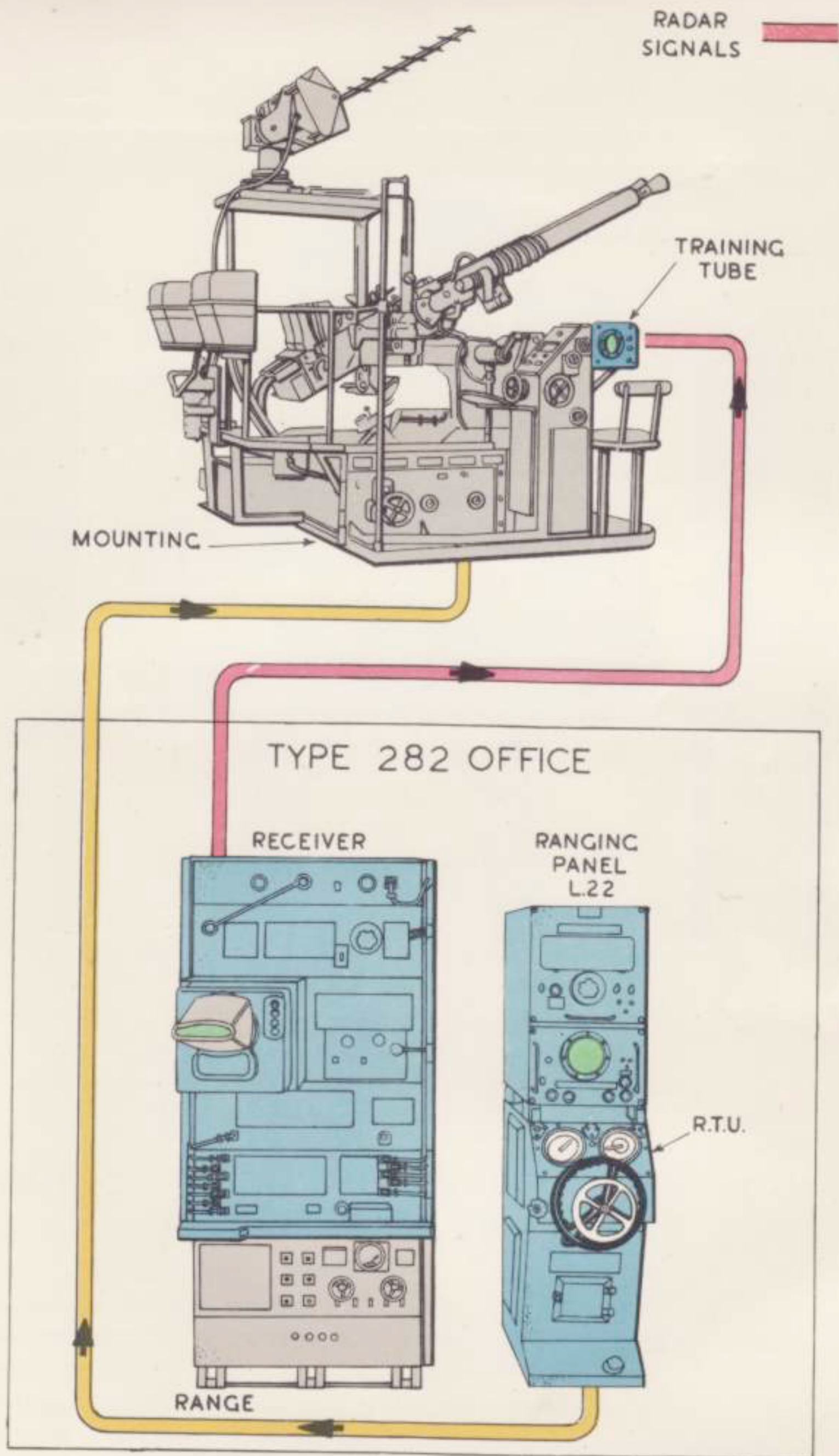


Fig. 51

LAYOUT OF GC TYPE 282 ON BOFORS MARK IV.
MOUNTING

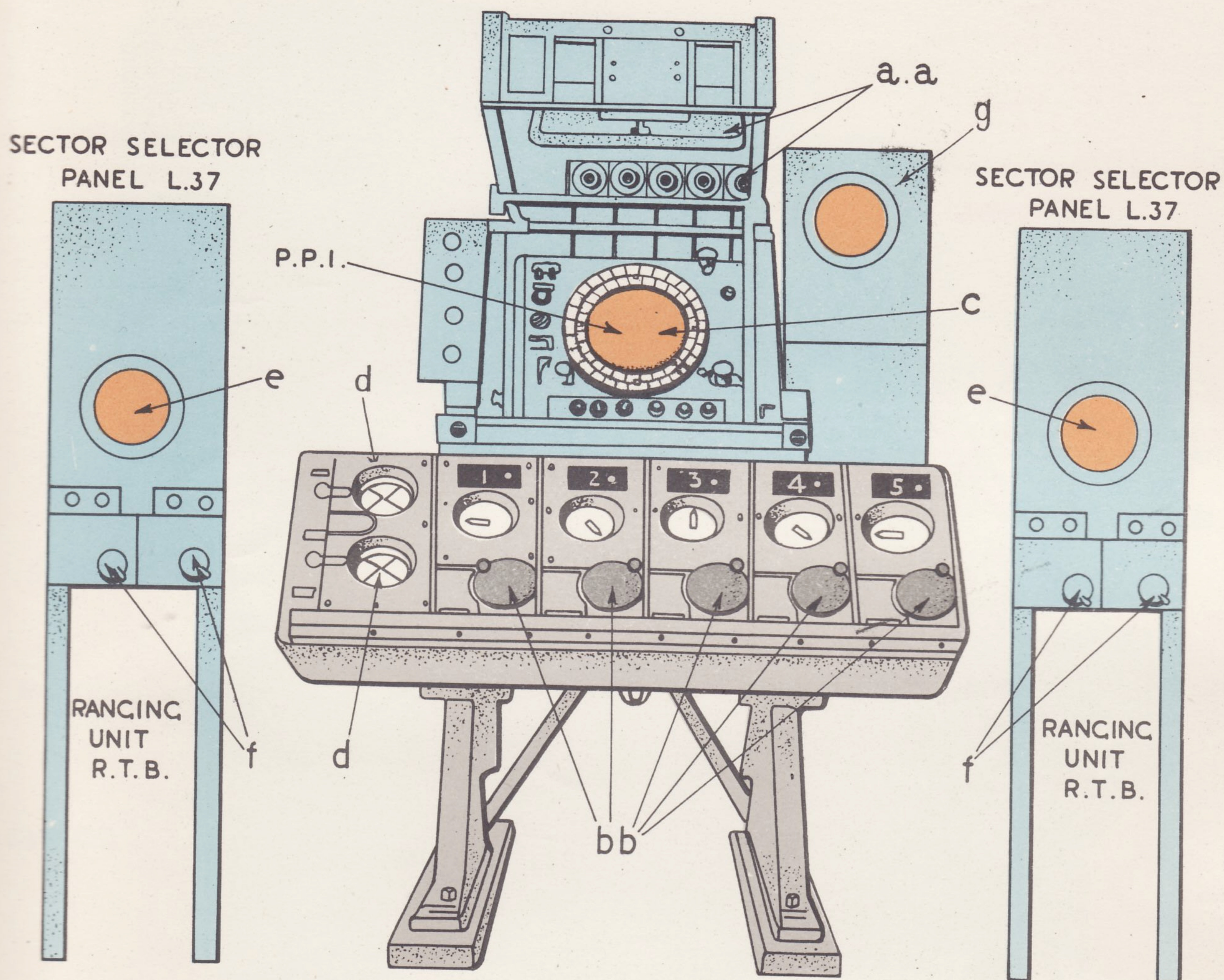


Fig. 52

LAYOUT OF TARGET INDICATION OFFICE WITH T.I.U. MARK IIB

showing :—

- a a — OVERHEAD OPTICAL SYSTEM
- b b — HANDWHEELS TO ALIGN OPTICAL BEARING LINES WITH SELECTED TARGETS
- c — FACE OF P.P.I.
- d d — AERIAL AND COMPASS REPEAT DIALS FOR LINING UP
- e e — SECTOR DISPLAYS FOR RANGING
- f f — HANDWHEELS FOR TRANSMITTING AWAY RANGE OF SELECTED TARGETS
- g — DISPLAY FOR INDEPENDENTLY CONTROLLED INTERROGATOR TYPE 242

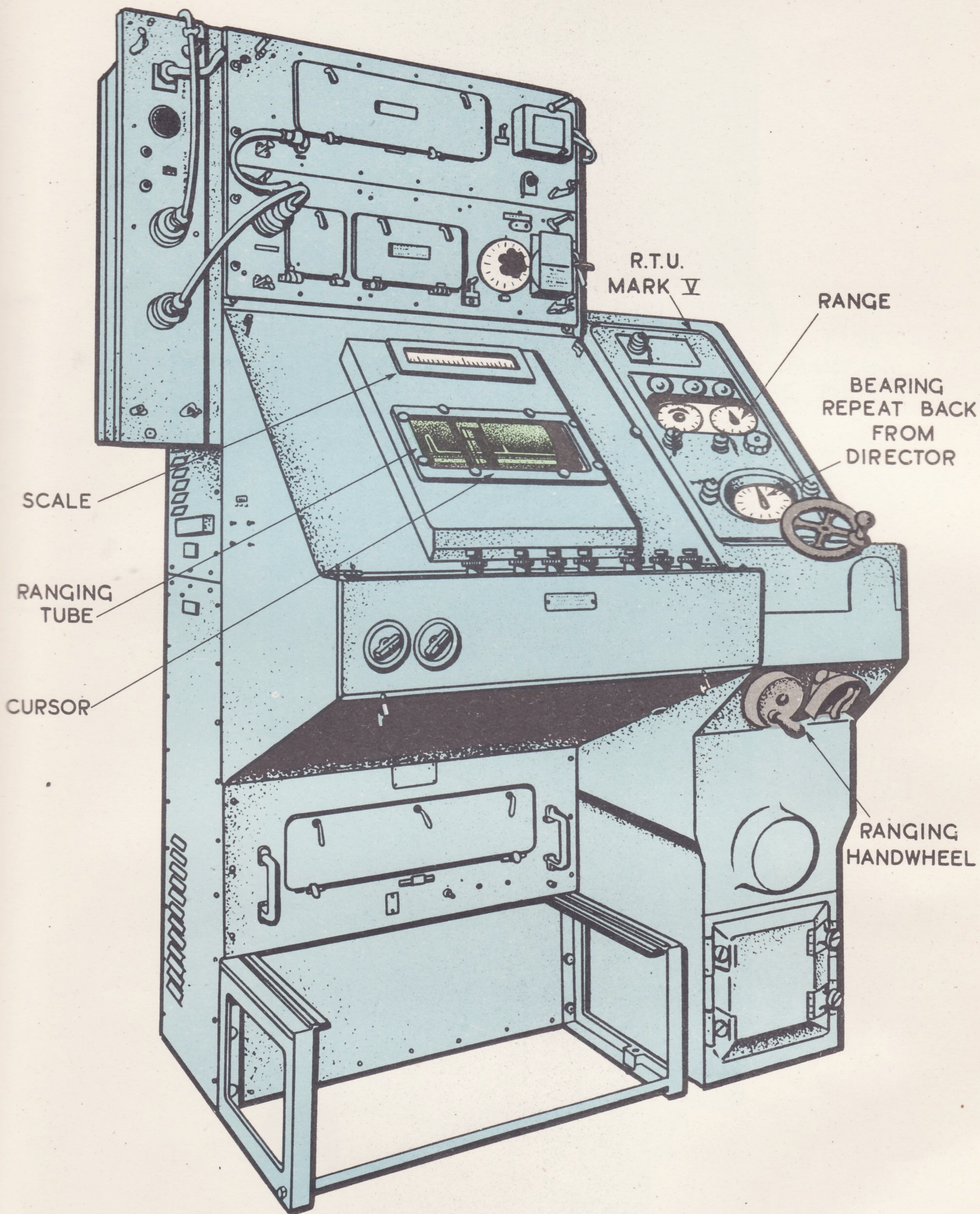


Fig. 53

RANGING PANEL L.12

Fitted in the Radar Office of GS Type 284 M and GA Type 285 M. This panel is obsolescent, R.T.U Mark V. is fitted with GA Type 285 M

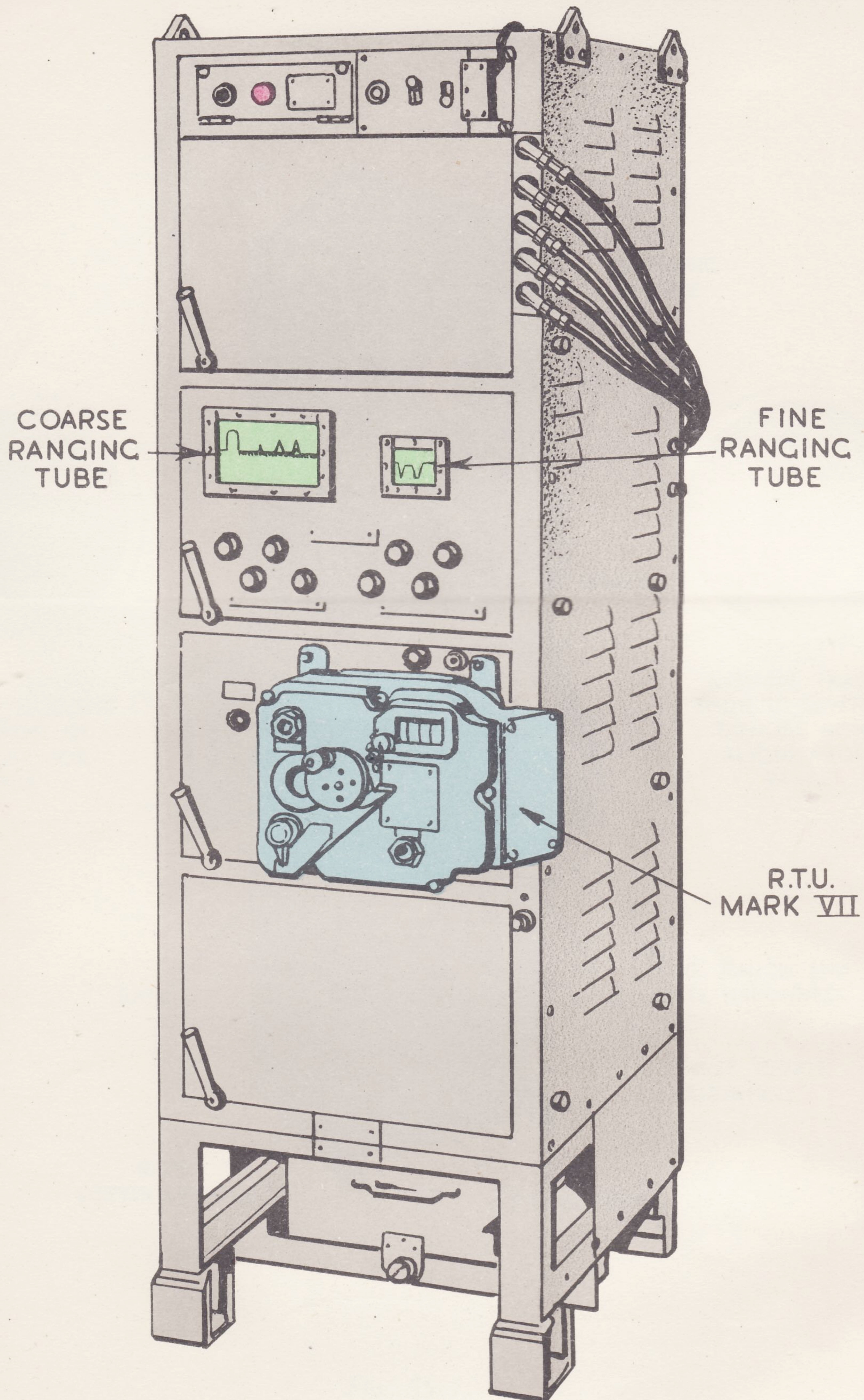


Fig. 54

RANGING PANEL L.24

Which in general replaces panel L.12 and is usually fitted in the T.S. or H.A.C.P. with GS Type 284 P or GA Type 285 P. R.T.U. Mark VII. is used with GS sets and R.T.U. Mark V. with GA sets

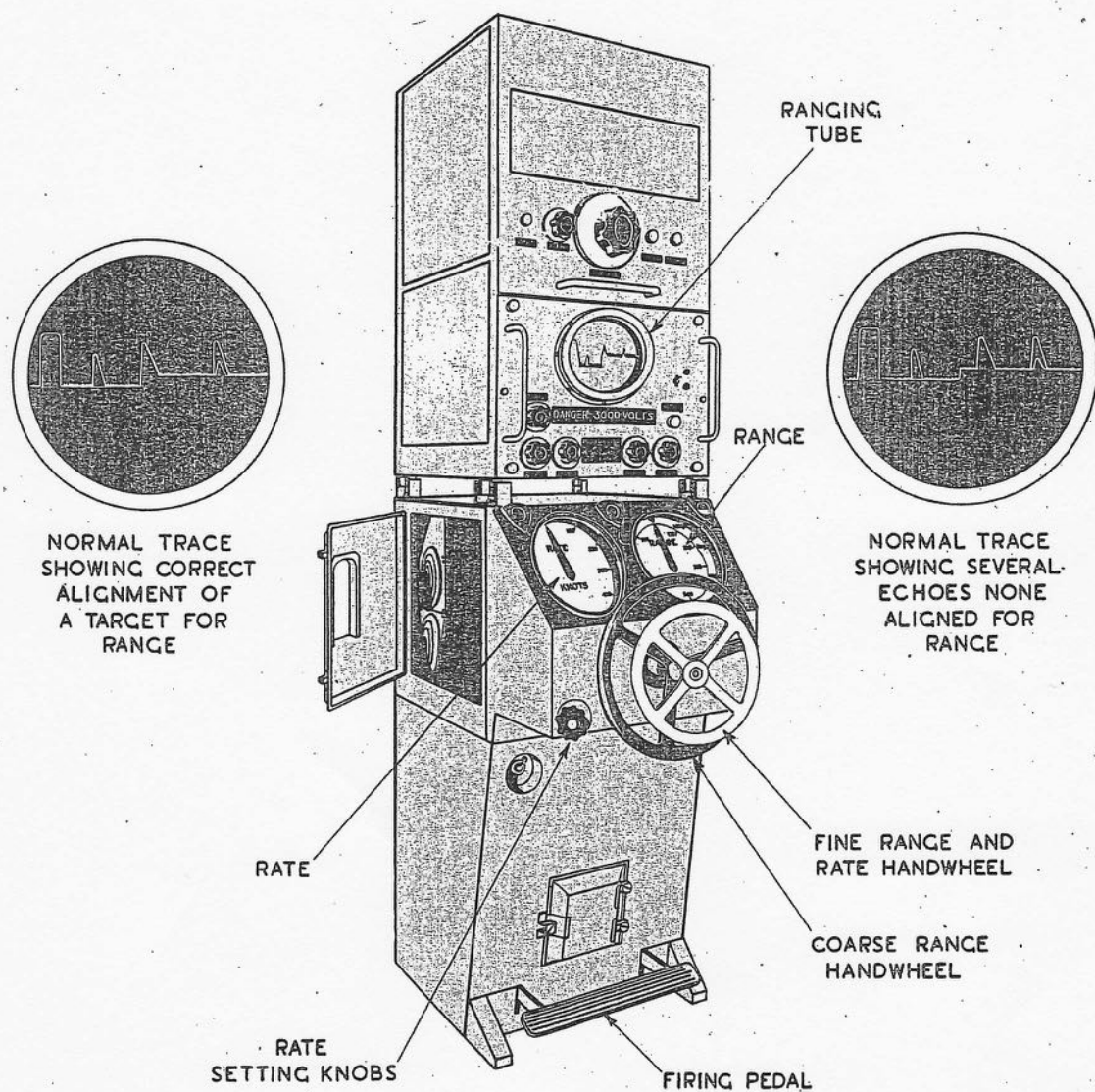


Fig. 55

AUTO BARRAGE UNIT

With ranging panel L. 22, used with GA type 285 and GB Type 283

Summary of performance of types 285 and 275 against surface targets

39. The following is a summary of the performance of types 285 and 275 against surface targets. In the case of type 275 the figures are forecast ones. For further details see *Chapter III* and *Appendix I*.

Type	RELIABLE RANGE		RANGE ACCURACY	RANGE DISCRIMINATION	BEARING ACCURACY	BEARING DISCRIMINATION
	Destroyer-Destroyer	Shell splashes (Destroyer armaments)				
285	10,000 yds.	8,000 yds.	25 yds. (285P)	200 yds.	15-30'	10°
275	20,000 yds.	12,000 yds.	20 yds.	100 yds.	15'	6°

Other radar sets used for surface ranging

40. On certain occasions warning radar sets are used for surface ranging, as described below.

41. **Old WS sets** (types 272PR and 273QR) were fitted with a remote accurate ranging panel L18 because they out-ranged the GS set type 284. The procedure was to use the WS set at long range, "handing over" and resuming sweep as soon as type 284 obtained a reliable echo. With type 284M/P, and even more so with type 274, this procedure should rarely be necessary. It is in any case undesirable to use a WS set for ranging if it can be avoided, as all round cover is lost and it interferes with the tactical function of the WS set.

42. **New WS and WC sets** (types 276, 277 and 293) are fitted with a sector display panel L37 which enables ranges of fair accuracy (200 yds. on short scale) to be passed to gunnery positions without stopping the sweep. Ranging by this means is a useful standby to the GS/GA set.

43. *No beam switching* is fitted to warning sets. Consequently, full blind fire by radar is not practicable with WS and WC sets since the bearing accuracy is not better than 1°, neither can it be accurately passed to the T.S. or director.

44. **WA type 281/B** is a fairly good surface detector and some sets may still have an accurate ranging panel which could be used if all else fails, provided lack of air cover can be accepted.

45. In small ships with only one radar (e.g., type 271Q, 291, 267 or 268) the set must necessarily be used when radar range is required and it is considered justifiable to stop the sweep. No special accurate ranging panel is fitted but accuracy of the order of 200-300 yds. from "A" display should be possible. With type 277 in small ships the sweep need not be stopped since a sector display is fitted, as explained in *para. 42*, but no R.T.U. is fitted and the range must be passed to the T.S. verbally.

HIGH ANGLE LONG RANGE GUNNERY RADAR

46. The problem is more difficult than shown in *Fig. 46*, because the third dimension is introduced.

47. The radar information required from GA sets is range, rate of change of range, and (for blind fire) line of sight for both bearing and elevation. Radar will supply these except that the present GA set type 285 will not give elevation. The successor, type 275, will do so.

48. The advantage that radar confers on H.A. gunnery is particularly evident in the accurate range and smooth rate obtainable. Visual ranging against fast targets is difficult and very dependent on the visibility.

49. H.A. spotting by radar is not at present reliable, but may become a practicable proposition with centimetric sets, i.e., type 275.

50.-52.

TYPES OF RADAR USED FOR LONG RANGE H.A. GUNNERY

Type 285 (*Fig. 49*)

53. Type 285 is the present standard GA set, and one is fitted on each H.A. Director and helps to control one "corner" of the ship's H.A. armament. Thus a Battleship will have 4 sets, a Cruiser 3 or 2, and a Destroyer 1 set, which is also used against surface targets.

54. Formerly, the ranging was done in the radar office (type 285M) and passed by R.T.U. to the H.A.C.P. (or T.S. in a Destroyer). In the modified sets (types 285P and Q) the accurate ranging panels are in the H.A.C.P. (or T.S.). Type 285 also has a remote training tube or radar bearing sight in the H.A. Director.

55. As stated previously, type 285 will not measure elevation and it is therefore not capable of full blind fire against aircraft. When rough elevation is required, for example for blind barrage, it must be obtained from the WA set or type 277 through the Height Filtering Position.

Type 275 (Fig. 50)

56. This will replace type 285 in ships fitted with Mark 6 or U.S. Mark 37 directors. Compared to type 285, type 275 has improved range discrimination, bearing accuracy and bearing discrimination. In addition it can measure elevation and so permit full radar blind fire. This it achieves by a "conical scan." Instead of the beam swinging right and left in the horizontal plane only, as happens with beam-switching in type 285, the beam is split into 4 lobes and each is energised in turn in rapid succession. Two pairs of split echoes are thus obtained; one pair is shown on the bearing tube, the other on the elevation tube. It should be mentioned that accurate elevation is *not* possible between $3\frac{1}{2}^\circ$ and $\frac{1}{2}^\circ$ elevation because the low lobe then gets distorted through reflection from the sea, while the high lobe remains unaffected. Below $\frac{1}{2}^\circ$ this does not have effect, and accurate measurement of elevation is again possible.

57. The range, elevation, and bearing displays and meters are contained in one panel L36 in the H.A.C.P. (or T.S. in a Destroyer). Remote bearing and elevation meters are also provided in the Director.

58. An H.P.I. will also be provided in the H.A.C.P. or T.S. for reasons explained in *para. 93*.

Summary of performance of types 285 and 275 against aircraft targets

59. The following is a summary of the performance of types 285 and the forecast performance of type 275 against aircraft targets. For further details see *Chapter III* and *Appendix I*.

TYPE	RELIABLE RANGE AGAINST MEDIUM BOMBER	RANGE ACCURACY	RANGE DISCRIM- INATION	BEARING ACCURACY	BEARING DISCRIM- INATION	ELEVATION ACCURACY
285	*23-40,000 yds.	25 yds.	200 yds.	15-30'	10°	Not possible
275	20,000 yds.	20 yds.	100 yds.	15'	6°	15'

* Depending on height of aerial and height of aircraft.

HIGH ANGLE CLOSE RANGE GUNNERY RADAR

60. The problem of close range H.A. gunnery is similar to that of long range H.A. gunnery as described in *para. 33*, though a much greater rate of change of bearing is usually encountered.

61. So far the biggest contribution radar has made to the problem is to provide accurate range. Radar range combined with the estimated rate of change of bearing and rate of the target allows a reasonably accurate "aim off" to be applied.

62. It should be mentioned, however, that, compared to GS and GA sets, the GC set has had an unlucky career. In its early days, it had frequently to be used as a source of supply for spares for the other 50 cm. (GS and GA) sets. Secondly, type 282 was the last of three to be fitted with beam-switching, and during a close range attack by several aircraft it was often impossible owing to the wide beam and absence of beam-switching, to be sure whether the radar was ranging on the same target as that at which the director was looking.

63. These days should now have passed, and types 282M and P should give the aid for which they were designed. The close range system as a whole is not, however, at present an accurate one. The successor will make allowance for movement of the target in all three dimensions, and radar type 262 will be used to "lock on" to the target and provide continuous range and rate, line of sight, and rate of change of bearing and elevation, so making full radar blind fire practicable.

TYPES OF RADAR USED FOR CLOSE RANGE H.A. GUNNERY**Type 282 (Fig. 51)**

64. Type 282 is the standard GC set and is mounted on Pom Pom directors and Bofors mountings in the majority of ships. The ranging panel is fitted in the radar office. The training tube, giving display of beam-switching, is normally on the gun mounting in the case of Bofors, or in the radar office in conjunction with R.P.C. of Pom Pom directors. In some cases, however, no bearing tube is fitted.

65. Ranges can be taken of aircraft up to the limit of the scale which is 6,000 yds. in type 282M and 7,000 yds. in type 282P.

66. Type 282 cannot obtain elevation. This is not such a great disadvantage, however, as with type 285, as full blind radar fire with type 282 is not aimed at: beam-switching for bearing is fitted primarily to ensure being on the right target, as explained in *para. 62*.

Type 262

67. Type 262 will be the successor to type 282 and should be a marked advance wherever it can be fitted, as it should make possible accurate blind fire against close range targets.

68. The complete set, including the 2-ft. parabolic mirror which forms the aerial reflector, is fitted on and forms an integral part of the gunmounting or director with which the set is associated. Type 262 will be fitted with the following close range systems :—

GUNMOUNTING OR DIRECTOR				TYPE
40 mm. Bofors twin S.T.A.A.G. Mark II mounting...	...	...	...	262(1)
Close Range Blind Fire Director ...	...	...	...	262(2)
Close Range System Mark I Director...	...	...	...	262(3)
B.U.S.T.E.R. Gunmounting ...	...	...	...	262(4)

69. The aerial system will scan 15° in azimuth at the same time elevating 50° on 3° steps. Simultaneously, it will search for range about the rough range of the target, "Lookout" bearing and range being provided continuously from the Target Indication System. When a target is picked up within the space thus searched, the aerial will "lock on" to the target and automatically follow it for range, bearing, and angle of sight. This will provide all the data required for prediction.

AUTO-BARRAGE FIRE

70. In barrage fire the object is to lay a curtain of steel through which an approaching target such as a torpedo bomber must fly. As regards lethal as opposed to psychological effect, this is of course an expensive business since many salvos will burst before and after the target has passed through the barrage.

71. The idea of auto-barrage is to make use of radar to enable one telling salvo to be fired at exactly the right range to hit. The target echo is followed in on a special radar display known as the auto-barrage unit, and the rate is thus measured. When the critical moment arrives, and provided the control of auto-barrage fire has been given to the radar office, the radar operator himself presses the trigger. If he is ranging accurately and the other necessary factors such as rate and deflection have been correctly allowed for, a hit should result. The firing range varies between 3,500 and 5,000 yds.

72. The Radar concerned is fitted with beam-switching primarily to make quite sure that the operator is in fact ranging on the same target as that at which the director is looking. Beam-switching does, of course, also permit blind fire, but elevation has to be provided from outside information, e.g., from the Height Filtering Position or direct from the WA or Height-finding set.

TYPES OF RADAR USED FOR AUTO-BARRAGE FIRE

73. Two types of radar are used for auto-barrage fire :—

(a) GB Type 283

This set is fitted on a special auto-barrage director and is used for auto-barrage control of main armament in Cruisers and secondary armament in Battleships. The Remote Bearing Tube is in the Director, and the A.B.U. (scale 0-7,000 yds.) in the Radar Office (*Fig. 55*).

(b) GA Type 285

An A.B.U. is fitted with each type 285 to provide for auto-barrage fire of the H.A. armament in Destroyers and above.

CONTINUOUS PREDICTION

74. An obvious disadvantage of auto-barrage fire as described above is that it means "putting all the eggs in one basket," and if anything goes wrong with the sequence of events (including the accuracy of ranging) there is no opportunity to fire another salvo. Alternatively, the enemy may drop his missile outside 5,000 yds.

75. The A.B.U. is therefore being replaced by a Continuous Prediction Unit whose scale is 0-12,000 yds. and which enables a series of "auto-barrages" to be fired.

76. Type 283M, to which type 283 will be modified, is fitted with the C.P.U. Mk. I. Type 263, an adaptation of type 262, will be fitted instead of type 283M in conjunction with the Medium Range System Mk. I to give continuous prediction.

TARGET INDICATION

77. Until recently, no precise form of radar target indication system was fitted, and indeed it was not an imperative need because the wide beams of earlier gunnery radar sets enabled them to be used for searching, also provided a rough look out bearing was given.

78. For surface targets this rough bearing was supplied from the WS set through the Tactical Plot to the GS set, and for aircraft targets from the WA set (or WC set in Destroyers) through the Aircraft Plot to the GA, GC and GB sets. The directors concerned were then swung to and fro until the target was picked up. In the case of GA type 285 it is usual to search with an elevation of 10° , which ensures detection of reasonably high aircraft without a marked loss in range against low aircraft or surface targets.

79. This rough and ready system is no longer acceptable for the following reasons :—
 (a) In order to improve bearing discrimination and provide other advantages, "modern" gunnery radar sets have much narrower beams than their predecessors and require to be "put on" to the target with greater precision. Comparative figures are :—

CLASSIFICATION	TYPE	BEAM WIDTH
GS	284	12°
	274	3°
GA	285	24°
	275	12°
GC	282	60°
	262	15°

- (b) With the increase of night air attacks by enemy aircraft, it is necessary to make full use of the ability of modern gunnery sets to carry out radar blind fire, and to make the best use of the limited ability of earlier sets. This can only be done by a Radar Target Indication Organisation, remembering that the A.D.O. himself can be of little help in the dark.
80. The requirements for a radar target indication set are that it shall provide accurate bearing, range, and elevation of all air and surface targets within 15 miles of the ship, and that the information shall be brought up to date at least once a second. This is necessary to compete with close aircraft, whose rate of change of bearing may be very high.

Type 293 and T.I.U. Mark II

81. A target indication set (type 992) is under development which will have a high rotation speed and will meet the main requirements except that for angle of sight. In the meanwhile WC type 293 is being fitted as the standard target indicating set in Destroyers and larger ships.

82. Type 293 has an aerial rotation speed of $7\frac{1}{2}$ or 15 r.p.m. and will detect all aircraft between 200 ft. and 20,000 ft. at 15–20,000 yds. (18–25,000 yds. with type 293M which has a larger aerial). Range against surface targets depends upon the height of aerial; typical figures are Battleship-Battleship 42,000 yds. and Destroyer-Destroyer 24,000 yds.

83. Target echoes are displayed on a P.P.I. in the Target Indication Unit which is situated in the Target Indication Room (see Fig. 52 and Photograph 77). An overhead optical system (a, a) throws up to 5 bright bearing lines on to the face of the P.P.I. A number of operators watch the P.P.I. and by turning handwheels (b, b) align the optical bearing lines with selected targets and thus automatically pass away the bearing to the L.A. and H.A. fire control rooms and directors where it is needed for putting on the gunnery radar sets. These sets may still need to search, but the search need normally only be a small one (type 262 and later type 275 will search automatically either side of the target).

84. Operating the bearing handles also has the effect of selecting a 6° sector of the P.P.I. and transferring this part of the picture on to a Sector Display Panel L37 which consists of a type of "A" display. Another operator is then able to take fairly accurate ranges (100–200 yds.) of the target shown on his display, and pass the range to the appropriate Fire Control Room. Range as well as bearing is necessary to indicate the target, since there may be several echoes on the same bearing; and in any case panel L 37 provides a useful check on the ranging set. With type 262, also, a "lookout" range is required because this set searches automatically in range as well as bearing.

85. The number of Sector Display Panels varies. A large ship has 2 and a small ship 1. Each display has two traces and can deal with two targets simultaneously.

86. The *Target Indicating Officer* is in charge of the Target Indication Room, which is normally situated in the A.D.R., and he selects the targets to be indicated from the T.I.U. under the general guidance of the A.D.O. (or P.C.O.). In Aircraft Carriers the T.I. Room is separate from the A.D.R. and in this case a *Gunnery Liaison Officer* is in the Aircraft Direction Room. He is in touch with the general air situation, and is able to keep the T.I. Officer informed of targets which will shortly come within range of type 293 and therefore appear on the T.I.U.

87. *Identification of Targets.* In the T.I. Room identification can be obtained or checked by means of directional interrogator type 242 fitted with type 293. Type 242 is independently controlled for bearing and can therefore interrogate any target required, displaying the response (if any) on panel L43. As a further check, each GA type 275 will have an interrogator.

Snags of type 293

88. *Bearing.* The rotation speed (15 r.p.m.) is not fast enough to compete with crossing targets at close range, and intelligent forecasting may be necessary. The bearing accuracy as obtained from the P.P.I. varies from $\frac{1}{2}$ –1° under favourable conditions up to 3–5° if the rate of change of bearing is high.

89. Additional error may be caused if the ship rolls or pitches as the aerial is not stabilised. This results in an apparently unsteady course of the target. A cross-level corrector is being fitted to allow for this.

90. *Range.* The range of detection is not as great as could be desired, and the WA and WS sets may have to supplement the T.I. set.

91. *Tactical function.* In small ships where there is no separate WS set and also in larger ships such as Carriers or other ships directing fighters, where the types 277, SM or SP may constantly be used for heightfinding, type 293 is also the surface warning set and therefore has a dual function—tactical and target indication. Warning demands the use of the long pulse length and a relatively slow rotation (*i.e.*, 7½ r.p.m.), which are the opposite of the target indication requirements. However, the change of rotation speed and pulse length takes little time.

92. *Elevation.* Type 293 cannot measure elevation. Information on height must be obtained from the Height Filtering Position (*see Chapter XI*) or direct from type 277, SM or SP if these sets are not being employed for tactical or Fighter Direction purposes.

93. Fortunately, the lack of elevation is not very serious, as with type 285 full blind fire is not possible. With type 275, once on the correct bearing a sweep in elevation is carried out until the target is located and the echoes balanced on the elevation tube. In addition, it is intended to fit a Height Position Indicator with type 275, for two reasons:—

- (a) To permit quicker sweeping in elevation.
- (b) As an insurance against breakdown of type 293. The procedure will then be to use a rough look-out bearing from the WA set and carry out elevation sweeps in elevation, at the same time moving the director in 4° steps of bearing.

94. GC type 262 will search through 50° of elevation as explained in *para. 69*.

BOMBARDMENT

95. In bombardment the problem is largely one of accurate navigation, which is dealt with in *Chapter IX*. Radar can be of assistance for firing in the following ways provided attention is given to obtaining good conditions:—

- (a) *Range and Bearing* can be obtained from a prominent mark such as a lighthouse. Range and bearing can also be obtained from a radar marker beacon (*e.g.*, type 950) or shore Radar Beacon (*e.g.*, type 258) if it has been possible to place these ashore. The range given may require a correction of 2–300 yds., but this can be found during preliminary practices.
- (b) *Range* can be obtained from bluff land, or from low land if special P.P.I. charts have been prepared (*vide Chapter XVII*). The U.S. Navy have carried out a number of successful bombardments from P.P.I. alone, and have found it useful to letter prominent points A, B, C, etc., for quick reference by all concerned.

96. Alternatively, position can be found or checked by other radio navigational means such as Gee and Loran, if available.

MISCELLANEOUS POINTS ABOUT GUNNERY RADAR

Range accuracy, range tests and checks, and calibration

97. These points are dealt with very fully in *C.B. 4112(I)* and other gunnery publications, and are only touched on briefly here.

98. *Range Accuracy.* This term is employed somewhat loosely in this book, though the general meaning will be understood. If a series of radar range readings is taken against a fixed target of known range the mean radar range may (and usually will) differ from the true geometric range due to the electrical constants of the radar circuit. The difference is known as the **Index Correction**, and radar range + Index Correction = True geometric range. The Index Correction should only vary from day to day a matter of a few yards provided the radar is properly set up.

99. However, not all the readings obtained against the fixed target will have been the same, due principally to human error of observation and reading off. The majority will be close to the "mean" point but some will be bad readings and lie some distance away. The "range accuracy" referred to in this book is the average distance of readings from the mean point (this should be known, strictly speaking, as the "range consistency"). Consequently, *once index correction has been applied*, radar ranges should not on the average differ from true geometric range by more than the figures given in this book. In a few cases the error may be larger, but in a great many more it will be smaller.

100. *Range Tests* to obtain the Index Correction for each gunnery radar should be carried out weekly. The normal procedure is to take the range of a shore Range Testing Mark which usually consists of a large sheet of wire netting mounted so as to form a good reflector. The ranging mark should be at a reasonable range and must be mounted in such a position that its echo is clear of all interference from land or other shipping. A series of readings is taken and compared to the true geometric range which must be known to an accuracy of 10–15 yds.

101. **Range Checks** for each gunnery radar should be carried out daily. They are carried out in the same manner as range tests but consist of a few readings only. Their purpose is to see that no sudden jump has taken place in the Index Correction, which would of course require an immediate full Range Test.

102. Other methods of carrying out Range Tests or Checks are as follows :—

- (a) Using two ranging marks simultaneously.
- (b) Using three ranging marks simultaneously.
- (c) Using a reflector in a ship's boat at short range, in conjunction with a visual range-finder.
- (d) Using double reflection from a nearby ship.
- (e) By comparison with the most consistent radar set.

Full details are given in *C.B. 4112(I)* which should be consulted.

103. The Index Correction once found is applied either in the R.T.U. or in the radar panel.

104. **Range Calibration**, not to be confused with a Range Test or Check, consists in firing a series of salvoes to find out the difference between true geometric range (= radar range + Index Correction) and the actual range of the gun. The difference is the **radar straddle correction** and should result in consistent straddling as explained in *para. 26*.

105. Radar range must therefore be corrected for two factors :—

- (a) Index Correction, which is constant and is due to the effect of electrical circuits, and is found by Range Tests.
- (b) Radar Straddle Correction, which varies with range and is due to error in the gun or range tables, and is found by Range Calibration.
- (c) can only be found occasionally, since it must be done at sea by firing. It is therefore all the more important that (a), the other factor, should be checked regularly, and obviously the Index Correction Setting must never be altered without the knowledge of the Gunnery and Radar Officers.

106. The results of all range tests and checks must be carefully recorded. It is usual to test and record the visual rangefinders at the same time.

Bearing and elevation accuracy tests

107. It is, of course, equally important to test bearing (and elevation) accuracy so that blind fire may be as good as possible.

Bearing can conveniently be tested against the ranging marks or other isolated shore objects ; or alternatively it can be tested against a ship (preferably end on) at sea. If necessary the radar aerial can then be realigned to the director as explained in the Technical Handbook of each set.

108. *Elevation* accuracy of types 262 and 275 must be tested against special balloons provided. Bearing accuracy can, of course, be tested at the same time. With type 262 jigs will be provided to check the relative position of waveguide and mirror, and this will check the bearing and elevation accuracy roughly.

Measurement of muzzle velocity.

109. It is possible to measure the muzzle velocity by means of Cine-camera cum radar. The method is, however, not very convenient and a new all-radar method is under development.

Approaching shells

110. Shells approaching own ship can be seen on the radar trace of a radar set pointing at the enemy, and have occasionally caused alarm and despondency. It has several times been suggested that the trace should be blanked off short of the target. This is not practicable for a number of technical and practical reasons. It should be explained to operators that the phenomenon is no indication of a hit as, owing to the wide beam at close range, salvoes that will be short, over, right or left, will all be seen. In fact, the appearance of balanced echoes outside the ground wave means a probable miss for line, since the path of the shell is a spiral.

Personnel

111. Radar Control (R.C.) ratings are provided to operate gunnery radar sets and man fire control rooms. Their organisation is discussed in *Chapter XXI*.

Use of gunnery radar for warning purposes

112. In the event of breakdown of warning radar, gunnery radar should be used—as it was used in the early days—to provide warning, even though this may involve keeping directors training for periods which are normally undesirable. For example :—

- (a) GS types 284 and 274 and GA types 285 will give good surface warning (particularly if mounted high up), and can also be used to provide low aircraft cover over a small sector.
- (b) GA type 285 will give useful aircraft warning out to 15–20 miles against aircraft up to 20,000 ft., or higher if the aerial is elevated, *vide C.B. 4112(5)*.

“New sets” versus “Old sets”

113. As explained in *Chapter IV*, the various types of radar sets and their successors have been for convenience, called “Old” and “New”; and the better performance expected from the latter will, no doubt, whet the appetites of every gunnery officer. To avoid disillusionment therefore it must be made clear that for a large number of reasons (non-availability of ships and unsuitability of directors being among them) it will be a long time before the majority of the Fleet will be re-equipped with “new” radar. Types 282-3-4-5 may be “Old,” but they have plenty of life to run yet. It is therefore important not to get the “Wait till we get 275” complex, but to realise that the vital thing to do is to squeeze the last ounce out of the gear that is actually fitted, and this applies both to operation (drill) and to technical performance.

CHAPTER XIII

USE OF RADAR FOR TORPEDO CONTROL AND SEARCHLIGHT CONTROL

1. The torpedo control problem is shown in *Fig. 56*. Unlike a shell, the torpedo is not affected by own ship's movement. Knowing the torpedo speed and range, the information required in order to fire a zone of torpedoes is:—

- (a) The enemy's course and speed, and previous movements, so that his future mean line of advance can be forecast.
- (b) The line of sight on firing to an accuracy of 1° , so that the correct "aim off" (called the "Director angle") can be calculated.
- (c) The approximate range of the enemy (say to 500 yds.) so that it may be known when he is within torpedo firing range.
- (d) Knowledge of the position of other friendly units, to ensure that they will not be endangered.
- (e) Identification of the target, including its size, so that the appropriate depth settings may be applied to the torpedoes. The likelihood of estimating size is fully discussed in *Chapter V*.

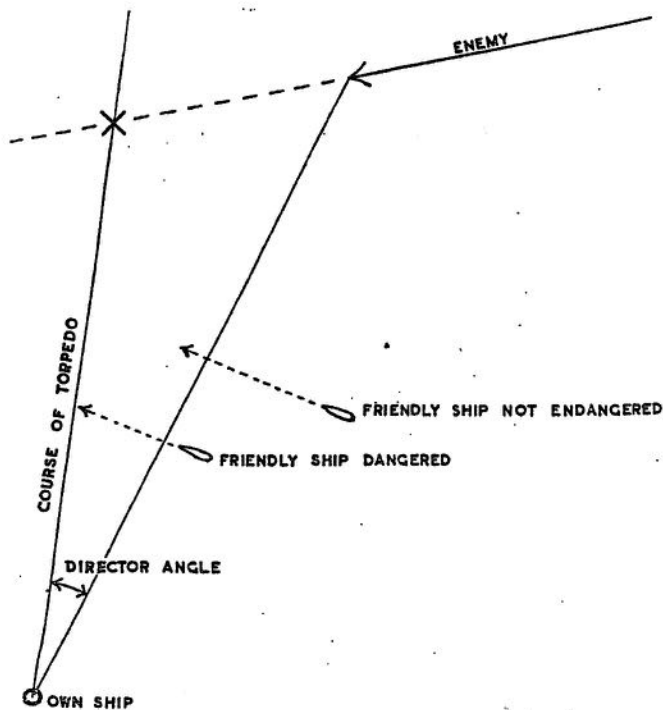


Fig. 56—The torpedo control problem. The torpedo must be aimed ahead of the enemy by an amount equal to the "director angle" in order to hit at X. To achieve this the enemy's course and speed, and bearing at the moment of firing, must be known. Own ship's course and speed do not affect the problem. It is necessary to ensure that friendly ships are not endangered.

2. WS radar using P.P.I. display can give all this information (except (e)) with sufficient accuracy, and radar information for torpedo control is therefore obtained from the P.P.I. and Local Operational Plot in the Operations Room and passed from there to the Torpedo Control Position. This procedure ensures that the Torpedo Officer is aware of the whole tactical situation, and not only the present bearing and range of the target.

BLIND TORPEDO FIRE

3. Blind fire at long range is expensive because not only is the effect of radar and torpedo error greater but there is more time in which the enemy may alter or even reverse his course, particularly if he suspects from his radar observations that we may have fired torpedoes. As against this, at very long range he may not have detected us at all and the attack may come as a complete surprise, though this is unlikely.

4. Blind fire may, however, be the only means of attacking with torpedoes. In this case one operator in the Operations Room reads off the P.P.I. bearing, which should be possible to an accuracy of 1°, and a second operator transmits away the bearing to the Torpedo Control Position. A special disc is fitted over the P.P.I. which enables the Torpedo Officer to tell at a glance whether other friendly ships will be endangered.

NON-BLIND TORPEDO FIRE

5. Radar information can be put to good use even if blind fire is not employed, *e.g.*:—
 - (a) The enemy's M.L.A. can be forecast and the general tactical situation seen at a glance from the P.P.I. and Local Operational Plot.
 - (b) Own ship or unit can therefore proceed so that the enemy is sighted on the best relative bearing for torpedo fire (if this is the primary object).
 - (c) The radar information will give an early lookout bearing and indication of the line on which the enemy is likely to be sighted, and supply data from which the director angle can be calculated and set on the torpedo sight before the target is visible. This enables the torpedo to be fired immediately the enemy is sighted and identified, and is particularly valuable in destroyers where the torpedo tubes can be trained in advance on the correct side and the direction of the turn to fire anticipated.

EFFECT OF RADAR SHADOW AREA ON TORPEDO FIRE

6. The cause and effect of radar shadow areas are explained in *Chapter VII*, q.v. One or more ships may be concealed by the radar shadow cast from an adjacent ship, or from the land. In the case of an action against several ships the effect of the radar Shadow Area is not however so detrimental to blind torpedo fire as it is to blind gunfire, as the bearing accuracy required is not so great and since a torpedo "zone" is fired the bearing of the centre of the unit (as opposed to the bearings of individual ships) may well be acceptable.

7. The radar shadow area cast round the coast line might well be put to our own use to execute surprise torpedo attack, either blind or visual.

SYNCHRONISED TORPEDO ATTACK

8. Some investigation has been made into the practicability of synchronising torpedo fire at night from destroyers placed in suitable positions relative to the enemy. It must be remembered however that drastic alterations of course by ships on firing will almost certainly be observed by the enemy's radar, and evasive action on his part is therefore likely.

9. For further details on the use of radar for torpedo control see *C.B. 4045 Torpedo Firing Manual* which is the authority on this subject.

10-19.

SEARCHLIGHT CONTROL

20. Although radar can provide an accurate line of sight, and when using P.P.I. can virtually "see" in all directions, it still suffers from the inability to provide positive identification and primarily for this reason cannot altogether replace the searchlight.

21. Radar can help searchlight control by:—

- (a) Providing an accurate bearing on which to expose the beam, thus avoiding or curtailing the dangerous period before the target is picked up.
- (b) Avoiding the necessity for sweeping an area by searchlight. There should be no need to expose the beam at all until radar has given warning that an object is in the vicinity.

CHAPTER XIV.

RADAR RECOGNITION (INTERROGATORS, I.F.F. AND RADAR BEACONS)

RADAR RECOGNITION

1. The inherent weakness of radar is its inability to distinguish at once and with certainty between those echoes that are friendly and those which are not. The object of the radar recognition system, loosely called "I.F.F.," is to fill this deficiency.*

2. This is done by the use of an Interrogator in the locating ship and an I.F.F. set (or "Responder") fitted in the located ship (if friendly), as explained in *Chapter II*, the two forming a radar recognition system which is subsidiary to, but an integral part of, the radar warning system.

3. I.F.F. has had an uphill struggle, for reasons explained later, and though it has not yet achieved finality the radar recognition system is much more reliable than it used to be. It still has its limitations, but these must not be allowed to discourage its use and development. Even if the system is not ideal, it provides at present by far the most secure form of recognition, and in fact the only one which can be used safely at night and so enable us to take full tactical advantage of radar, especially in the offensive use of blind fire.

4. For these reasons it is the duty of executive officers to be just as conversant with the rules for the use of interrogators and I.F.F. as they are with the older established visual recognition systems. The precise radar rules are laid down in *C.B. 04092/44* and amplified in Station Orders: the remarks in this chapter should be taken only as a guide.

5. Before going further it is as well to be clear about the difference between I.F.F. and radar Beacons. The object of the Recognition system (Interrogator plus I.F.F.) is to provide recognition between friend and foe, or between one or more friendly units. The range of the system should therefore only equal or perhaps slightly exceed that of the associated location (warning) system, and this is what is aimed at. The object of a radar Beacon on the other hand is primarily to afford homing or navigational facilities, so a beacon is made as powerful as practicable in order to give maximum range. In practice, as explained later, an I.F.F. set is sometimes used as a short range beacon, while a radar Beacon can be used for recognition, in certain circumstances. This does not, however, affect the primary object of these devices and therefore their design.

Development of the recognition system

6. Early I.F.F. sets (Marks I and II) responded direct to the transmissions of the location radar sets, which were therefore their own interrogators. As more radar sets and wavelengths came into service this system became impracticable; for one thing it would have been impossible to make a compact I.F.F. set covering 3 cms. to $7\frac{1}{2}$ metres. It was therefore decided to use one special waveband for the radar recognition system, and this gave rise to the necessity for a separate interrogator, *i.e.*, a subsidiary radar set, to be associated with each warning location radar set and such gunnery radar sets as require their own recognition facilities.

7. An exception to the rule of "separate band interrogation" is that aircraft use $1\frac{1}{2}$ metre A.S.V. (Mark IIN) to interrogate direct, in order not to overburden them with equipment. Modern A.S.V. working in the decimetric or centimetric bands, requires a separate interrogator which is known as "Lucero."

8. The early troubles of I.F.F., which gained it such notoriety, were due to:—

- (a) the fact that I.F.F. Marks I and II only responded to a few radar sets;
- (b) the fact that many aircraft and most ships were not fitted with I.F.F.;
- (c) technical unreliability.

9. These deficiencies have to a large extent been surmounted with the Mark III system which is now the standard allied equipment.

* It should be noted that S.P. 02220 (Recognition Manual) lays down that **Recognition** consists of a challenge and an identification signal (reply), and **Identification** of a spontaneous signal meaning "I assume you to be a friend." The use of radar Interrogators and I.F.F. therefore constitutes a Recognition System. In the R.A.F., however, the term "Identification" is used when distinguishing aircraft out of sight and "Recognition" when aircraft can be distinguished by actual features of their appearance or by special visual signals.

THE MARK III SYSTEM—I.F.F. MARK III AND TYPE 253

10. In the Mark III system the interrogators commonly used are types 242 and 243. When interrogating, radar energy is sent out and if this strikes a friendly transponder the latter is "triggered" into life and sends back a distinctive response, usually on the same wavelength, to indicate friendly character. The transponder is called *I.F.F. Mark III* if fitted in aircraft and type 253 if fitted in ships. In the U.S. Navy they are known as ABK and BK respectively. They are all identical.

I.F.F. MARK III GIVES CHOPPED RESPONSE ON SEPARATE FREQUENCY
FOR $\frac{1}{15}$ SEC. FOR REMAINING $\frac{4}{15}$ SEC. SWEEPS A-BAND

TYPE 941 209

G-BAND

INTERROGATORS

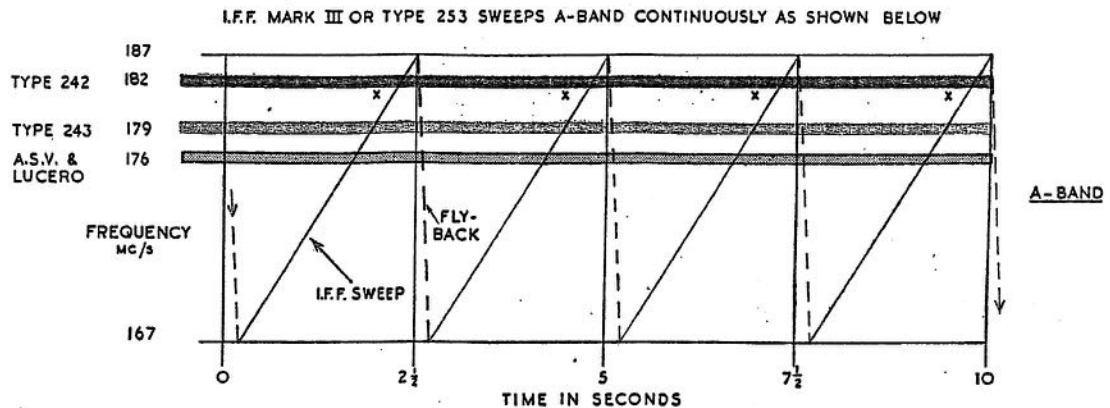


Fig. 57—Operation of I.F.F. Mark III (and type 253) showing also the Interrogating frequencies in naval use. For example, Interrogator type 242 will trigger I.F.F. at the moments marked X X etc.

11. When switched on, the I.F.F. searches continuously over a small waveband (in frequency 157 to 187 megacycles per second) called the "A" Band, ready to be triggered by an interrogator. This is shown in Fig. 57. The object of the sweep is two-fold:—

- It guards against Interrogators being off tune.
- It allows Interrogators of different services or functions to be grouped separately, thus avoiding mutual interference.

In the R.N., WA Interrogators (type 243) use 179 mc/s.; WC and WS Interrogators (type 242) use 182 mc/s.

Coding

12. The I.F.F. sweeps its waveband every $2\frac{1}{2}$ seconds and under normal conditions will therefore send back a response every $2\frac{1}{2}$ seconds provided the beam of type 243 or 242 is pointing towards it. This response may take the form of a narrow pulse, a wide pulse, or a very wide pulse, and it is normally displayed in a downwards direction on the "A" display of the parent set where it can be easily related to the location echo, as shown in Fig. 58. Actually the I.F.F. response appears at a slightly greater range (about 200 yds. for a strong response and up to 500 yds. for a weak response.)

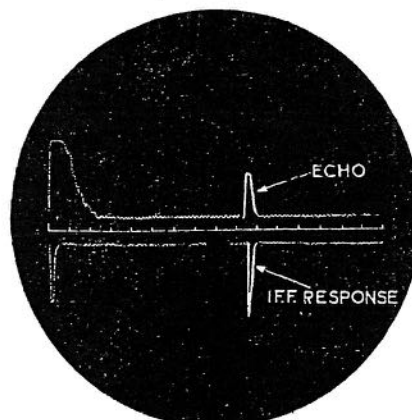


Fig. 58—Narrow I.F.F. response on "A" Display, with associated location echo.

13. The response can be varied, as between narrow (N) or wide (W) or a combination of each, by switching the I.F.F. coding to one of 6 positions which are :—

- | | |
|--------|---------|
| No. 1. | N N N N |
| No. 2. | N — N — |
| No. 3. | N N N — |
| No. 4. | N N W W |
| No. 5. | N — W — |
| No. 6. | N N W — |

that is to say, provided the interrogator is kept pointed towards the transponder, the response will be a narrow pulse every $2\frac{1}{2}$ seconds in the case of Code No. 1 ; in the case of Code No. 4 the first response will be narrow, the second narrow and the next two wide, each response being separated by $2\frac{1}{2}$ seconds of time as the I.F.F. set sweeps through its waveband, and the whole cycle therefore taking 10 seconds. It will be observed that Codes 2, 3, 5 and 6 give no response at certain times. It follows that the interrogator must be kept trained towards the transponder for 5 seconds to make sure of getting a response at all, and establishing friendly character and for 10 seconds when it is desired to read the code. *Fig. 59* illustrates the appearance of successive responses when using code number 6.

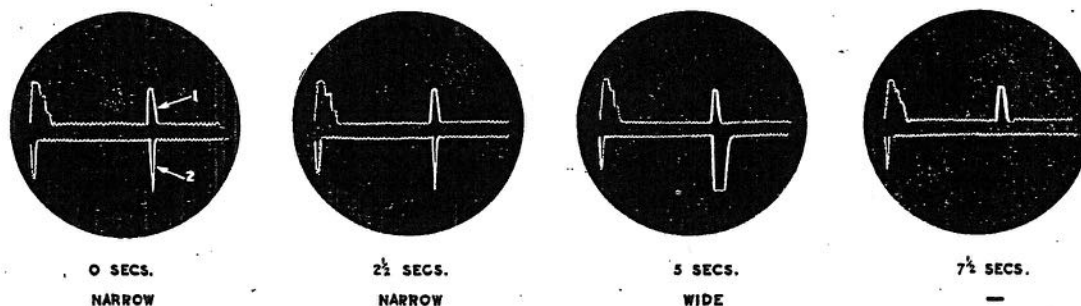


Fig. 59—Complete Coding cycle of I.F.F. Mark III (or type 253) showing Code number 6. 1. Echo. 2. I.F.F. response.

14. Coding is provided in order to distinguish between different friendly units, or to recognise a unit performing some special task. The rules for using codes are indicated in *para. 58*.

15. A very wide pulse is also available and is reserved for use in emergency. It is known as the **Distress Code**.

16. Type 253 has a special conical aerial designed to give an all-round coverage diagram so that a response can be given from whatever direction the ship is interrogated.

17. **The policy for fitting is :—**

- Aircraft.* All operational aircraft should be fitted with I.F.F.
- Warships.* All warships down to and including Coastal Force Craft should be fitted with type 253. Large ships will be fitted with two sets, one being a stand-by: destroyers, etc., will be supplied with a spare.
- Merchant Ships.* Certain fast independent merchant ships may be fitted with type 253, primarily to avoid attack by allied aircraft.

18.-19.

INTERROGATORS TYPES 242 AND 243

20. Details of interrogators are contained in *Chapter III*. Briefly, interrogators can be divided into the following categories :—

- Directional and rotatable* such as type 243/M fitted with WA sets, and type 242 when fitted with WS sets. In some cases the Interrogator aerial is fitted on to the top of the locating aerial and rotates with it, and in others it is fitted separately and rotates in synchronism with the locating aerial. With new WS and WC sets, where the locating aerial spins, the interrogator type 242 is fitted and controlled independently. (See also type 243Q *para. 92*.)
- Directional and fixed*, such as type 242 fitted with WC sets in coastal force craft. Ahead coverage only is given. The aerial consists of two parts, set at an angle, and beam-switching is used to provide bearing. The craft must be swung so that the response is ahead when accurate bearing is required.
- Non-directional*, such as type 242 fitted with WC type 291 in small ships. Range only is given.

21. The main weakness of naval interrogators is their poor bearing accuracy, which arises because there is only room to fit a small aerial array. As a result :—

- (a) It is necessary on "A" display to sweep right and left to get "cut off" bearings of a response, and the accuracy is seldom better than 5–10°.
- (b) Owing to the extent of the horizontal coverage diagram responses are received over a wide arc which may be as much as 200° at short range.

22. Consequently the primary method of relating I.F.F. response to location echo is by means of range, and the disadvantage of non-directional interrogators is not so great as might be imagined.

23.–24.

CAPABILITIES OF THE RADAR RECOGNITION SYSTEM

25. As stated previously, the object is to be able to obtain recognition at the same range as location, or perhaps a slightly greater range in order to allow for anomalous location conditions.

26. In aircraft detection this is amply achieved, and rough tracking of friendly aircraft by their I.F.F. response can be carried on outside location range (*e.g.*, when the aircraft is very low, or very far away), or when the aircraft is in a gap of the location set's vertical coverage diagram. This is often of considerable operational value, particularly in the case of A/S escort aircraft circling over a U-boat.

27. In surface detection by modern high powered centimetric sets the recognition range with type 242 is less than location range. Type 242M is therefore being fitted and its higher power should ensure recognition at least before blind fire becomes practicable.

28–29.

LIMITATIONS OF THE RADAR RECOGNITION SYSTEM

Technical troubles. Importance of tests

30. Like other forms of radar developed hastily in war, Interrogators and I.F.F. are not 100% reliable. Apart from possible failure through I.F.F. not being switched on at all (which is not as common as is generally supposed), failure of the system may be due to the Interrogator or the I.F.F. set, or both.

Interrogators

31. It is important that the wavelength of both the interrogator and its receiver (responder) should be carefully checked. They are frequently found to be out of tune. It is also important to find by trial the bearings over which the Interrogator is inoperative, or its efficiency is reduced, due to screening from the ship's superstructure.

Type 253 and I.F.F.

32. This may also be screened, and it is obviously in the interests of the ship's safety to ensure that the best clear high site is selected for the aerial, and that its all-round view is not disturbed by the subsequent fitting of some new device. As much care and precision should be devoted to siting the type 253 aerial as is paid to siting navigation lights.

33. Partial screening of the I.F.F. in aircraft is often inevitable, particularly in flying boats, but every effort is made to provide a clear arc ahead so that approaching friendly aircraft may be identified at once.

Testing the system

34. It is obviously of first importance to test the system regularly, and it is recommended that this should be done as a matter of routine on proceeding to sea. The procedure is to order I.F.F. to be switched on in all ships and for each ship to interrogate all the others in turn, thus checking both the interrogator and type 253. Alternatively, a special shore station can be fitted to carry out tests with ships leaving harbour. In either case the test should be carried out at the maximum distance practicable, provided it is within location range.

35. On board, rough tests may be carried out as follows :—

- (a) By disconnecting the suppressor unit, own ship's interrogator will trigger type 253 and obtain a form of response if type 253 is working.
- (b) A coloured lamp is fitted on the bridge to indicate when type 253 is being triggered by other ships' (or aircraft's) interrogators. Although it is likely to be triggered by extraneous transmissions also, and therefore is of limited operational value at present, it provides a good guide to whether type 253 is "alive."
- (c) Large ships are being provided with a test set which should be used daily.

Reporting failures

36. Failure to receive responses from friendly ships or aircraft under circumstances when their I.F.F. should be switched on and own ship's interrogator is known to be working properly should always be reported on return to harbour, in order to enable an investigation to be made. Only by this means is it possible to raise and maintain a good technical and operational standard.

Clutter

37. Unwanted and even wanted I.F.F. responses can clutter up and so confuse the radar display for two main reasons:—

- (a) The lack of bearing accuracy and discrimination of interrogators.
- (b) Through the use of too many interrogators and I.F.F. sets in one area.

Lack of bearing accuracy and discrimination

38. As has been stated, the horizontal coverage even of a "directional" interrogator is very wide, and therefore responses are received from all I.F.F. sets within range over a wide arc, and not only from the exact direction in which the interrogator aerial is pointing. This naturally confuses the display and makes it slower to sort out what is really required. There is also a risk that an enemy may at first be "identified as friendly" if he is at the same range as a friendly craft and within the bearing discrimination. In the case of aircraft, which are not likely to remain at the same range for long, the mistake should soon become evident.

39. When the Interrogator aerial is fixed to the location aerial of a set which is sweeping in azimuth a further trouble arises because the I.F.F. set itself is searching a waveband and it may not coincide with the interrogator's wavelength until $2\frac{1}{2}$ seconds (or with some codes 5 seconds) after the interrogator has swept past the bearing of the I.F.F. set.

A response may then be received which is considerably out for bearing. Owing to this limitation and the very wide response echo which would be painted in any case, direct display of "A" band responses is not practicable on P.P.I. or Skiatron (see Fig. 60) and this is the reason why separately controlled interrogators have to be used with continuously sweeping sets, the response being shown on a sector display. In order to give direct display of own fighters G-band I.F.F. response, special methods are used (para. 86).

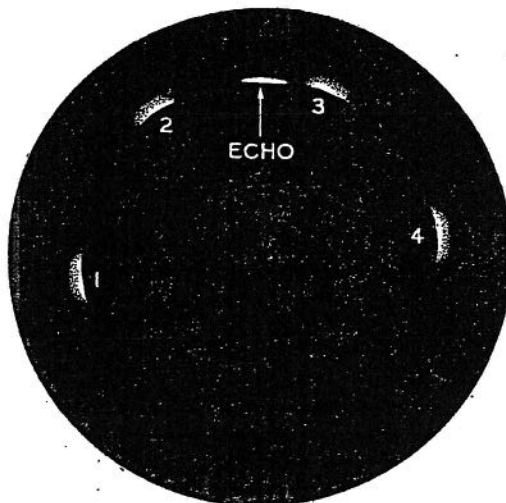


Fig. 60—Showing effect that would be obtained by attempting to display "A"-Band I.F.F. response direct on P.P.I., with the Location and Interrogation aeriels sweeping in synchronism. 1, 2, 3 and 4 show typical positions of the unrelated response. (N.B. Only one response would appear each sweep, and succeeding positions would differ.)

40. Too many interrogators and I.F.F. sets in one area will obviously clutter up the radar scan. Responses will be shown (at the right range) not only from all I.F.F. sets triggered by own ship's interrogator but also (at the wrong range) from the "unlocked" responses from I.F.F. sets triggered by other ships' and aircraft's interrogators. It is therefore necessary—

- (a) to switch on interrogators only for so long as is actually necessary;
- (b) under normal conditions to restrict the use of I.F.F. to one ship or aircraft in a unit, when in close company;
- (c) in the case of large operations, to "ration" still further the use of I.F.F. in congested areas.

Over-interrogation

41. The capacity of an I.F.F. set is limited and it will therefore give weaker response and therefore less range the more interrogators are triggering it. This is a further reason for restricting its use in congested areas.

Security

42. The chance of an I.F.F. response signal being intercepted and D/F'd by ordinary means is practically nil, and it should be remembered that even when switched on there is no actual transmission until triggered. Where a danger does arise is in the possible use by enemy aircraft or ships of radar whose wavelength lies within the I.F.F. band; this would present him on a plate with valuable recognition and homing facilities since he would observe the

range and bearing of the distinctive response direct on his radar display. Should intelligence suggest the likelihood of this happening the fact would be promulgated by Admiralty or Commanders-in-Chief. The development of more secure shipborne transponders (similar to types 951 and 952, *paras. 144 and 145*) is under consideration.

Simulation

43. Another possibility that must always be borne in mind is that the enemy might copy our I.F.F. or use a captured specimen. Remembering the length of time it took us to develop and fit the Mark III system, this evil is never likely to become widespread, but in penny numbers it might be most annoying and might tend to destroy confidence in the system. Unfortunately, some nations are born copiers.

Summary

44. It will be seen from preceding paragraphs that I.F.F. is not at present 100% dependable, and lack of response cannot therefore be taken as establishing hostile identity. It should be regarded rather as a very useful *quick* means of establishing friendly identity (except in the unfortunate circumstances referred to in *para. 43*), and whether I.F.F. is showing or not other evidence should be taken into account, *e.g.* :—

- (a) Knowledge of movements of friendly craft.
- (b) Direction of approach and general behaviour of targets as plotted.
- (c) "Y" and other intelligence.

45-49.

RULES FOR USING I.F.F. SETS AND CODES AND INTERROGATORS

50. Precise rules for using I.F.F. and Interrogators are laid down in C.B. 04092/44 and station orders, and the following is only a summary and guide.

When to use I.F.F.

51. **Ships.** The Senior Officer is responsible for ordering the **I.F.F. State** which is normally either "I.F.F. ON Continuously" (State K) or "I.F.F. OFF" (State J).

52. *I.F.F. should be on whenever it may be of value, e.g. :—*

- (a) When the visibility is less than horizon range (since this range is normally achieved by surface location sets) and there is any chance that enemy forces may be in the vicinity.
- (b) Always when the enemy is known to be in the vicinity and other friendly forces may be also.
- (c) When making a rendezvous with Allied-warships, when it should be switched on an hour before radar contact is expected.
- (d) When the I.F.F. set is being used as a short range beacon for aircraft, *vide para. 122*.

53. Failure to switch on I.F.F. in the above circumstances, either due to forgetfulness or due to fear of D/F, etc., may have serious consequences which are likely to be more serious as the efficiency of blind gunfire and blind bombing increases. A cruiser, not showing I.F.F., was recently straddled by depth charges from a long-range aircraft.

54. When ships are in close company the Senior Officer will detail an **I.F.F. Guard** (normally his own ship), in order to avoid cluttering other ships' radar display as explained in *para. 40*. If a ship temporarily parts company I.F.F. should be switched on, and it is most important to remember to switch or keep I.F.F. on whilst rejoining the unit in low visibility, or a false alarm may be caused.

55. *I.F.F. should not be switched on because it is not necessary and only wears out the equipment, e.g. :—*

- (a) when it is highly improbable that enemy forces are in the vicinity, and this fact is generally known ;
- (b) when no other friendly forces are likely to come within radar range (this includes aircraft at night) ;
- (c) with horizon visibility (unless I.F.F. is required for the purposes explained in *para. 52* (c) and (d)).

56. *When coasting* and within 25 miles of the land I.F.F. state "L" is adopted. This consists in switching the I.F.F. on for a selected 10 minutes in each hour as laid down by the local Commander-in-Chief or Flag Officer (*vide C.B. 04092/44 Section 11*). The object of this is to enable shore radar plots to recognise friendly units and to assist in tracking them. State L is automatically replaced by State K if enemy forces approach.

57. **Aircraft.** The rules for aircraft differ somewhat in each area, and are tempered by a reluctance to use I.F.F. near enemy territory for fear of gratuitous warning and recognition. As far as co-operation with ships is concerned, however, there *should* be no trouble as the rules in every case allow for I.F.F. being switched ON when over the sea and friendly warships are known or believed to be sailing in the area. However, there are inevitably occasions when the aircraft is for some reason or another unaware of the presence of ships in her vicinity, and may not therefore have switched on I.F.F.

Use of I.F.F. Codes

58. No. 1 is the normal code for ships and aircraft. Other codes are used to distinguish between different friendly units (such as sections of fighters, or between reconnaissance and fighter aircraft), or to distinguish craft engaged in some special task such as shadowing.

59. *Universal allocations* are :—

No. 4—A ship or aircraft engaged in shadowing enemy ships or submarines on the surface, while they are actually in contact.

No. 6—Shore-based fighters (who will always be within 150 miles of the land).

60. This leaves numbers 2, 3 and 5 (and also No. 6 when more than 150 miles from the land) for allocation by Senior Officers who should whenever possible inform other authorities concerned of the allocation. Typical allocations at present in force on various stations are :—

No. 3—For homing an A/S escort on to a convoy or unit when it is not desirable to use the high-powered beacon type 251M.

No. 5—For use by aircraft over a U-boat after the latter has dived.

No. 6—For use, on request, by aircraft over a convoy (more than 150 miles from Allied territory) in order to assist Allied warships to close the convoy.

61. *Distress Code.* In addition to the 6 codes above there is a special distress code for use in emergency, to which ships or aircraft may switch if necessary. This will assist in the identification by radar of ships and aircraft which have sent distress messages and, in cases where no such message can be sent, will in itself indicate distress.

62. The distress code may also be used :—

(a) By a ship *after* having asked for a shore navigational fix, as explained in *Chapter IX*.

(b) Subject to station orders, by an aircraft circling survivors.

63-64.

When to use Interrogators

65. Unlike I.F.F., an interrogator can be intercepted and D/F'd and unfortunately the wavelength lies within the band on which it is known that some German interception receivers operate. For this reason the unrestricted use of Interrogators is not always permitted and is governed by the Radar Policy in force, *vide Chapter XIX*.

66. Restrictions on the use of interrogators should, however, be rare, for the following reasons :—

(a) The power is low ; type 242 is only 1/100th the power of type 291, type 242M is 1/10th. The interception range is therefore comparatively small.

(b) The interrogator is not (or should not be) used continuously, but only in single bursts of 5-10 seconds in one direction.

67. It must also be remembered that interrogation is by far the safest form of obtaining recognition in low visibility, and should therefore be the primary means of challenging. It is recalled that on several occasions A/S escorts (fitted with type 242) have illuminated by searchlight or starshell a " U-boat " which turned out to be another escort (fitted with type 253). In such cases the advantage of using the interrogator clearly far outweighed its possible danger.

68. Interrogators and I.F.F. have also proved useful for :—

(a) Tracking an A/S air escort flying too low for detection.

(b) Tracking fighters outside location range, and through gaps in the vertical coverage diagram.

(c) Making a rendezvous with aircraft (showing I.F.F. Code 4 or 5) over a U-boat.

69-70.

DESTRUCTION OF I.F.F. IN EMERGENCY

71. I.F.F. and type 253 must not be allowed to fall intact into enemy hands. When fitted in aircraft, merchant ships, and small surface craft a destructor device is fitted which should be operated in emergency, as described in *C.B. 04092/44, Section 14*. If the destructor fails, or is not fitted, the transponder should be burnt or broken up and thrown overboard in deep water.

72-74.

VARIATIONS OF THE MARK III SYSTEM

75. The preceding paragraphs describe generally the plain straightforward Mark III system. Certain variations of the Mark III system will now be mentioned. Future developments are mentioned in *paras. 100 and 104*.

Type 253P

76. Type 253P will replace type 253 in ships and contains modifications designed to reduce the insecurity of the Mark III transponder. The modification consists of two features :—

- (a) Morse coding which can be used, in addition to the 6 normal narrow and wide codes, in order to confirm friendly identity or to distinguish a particular ship or unit.
- (b) Means of reducing the power of the transponder, so reducing the risk of enemy aircraft homing on to own ship.

77. There are three alternative conditions :—

- (i) *Button A.* Every alternate 5 seconds the transponder carries out two normal sweeps on "A" band, the power of the transponder being reduced, if desired, for the reason given above. During the other 5 second periods the response consists of a two-letter morse signal on a fixed wavelength, namely that of the WS interrogator type 242 (182 Mc/s.). This response can be read off the display by the radar operator (if trained), or by a communication rating detailed for the purpose.

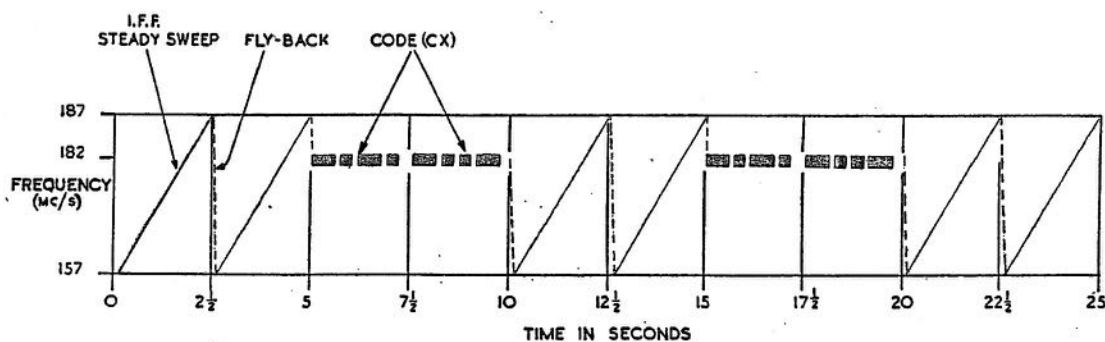


Fig. 61

Fig. 61—Illustrating the operation of type 253P on Button "A." For alternate periods of five seconds the I.F.F. sweeps the normal A-Band (giving narrow responses when triggered). During the remaining periods a preset coded response is given (when triggered) on the frequency of Interrogator type 242.

- (ii) *Button B.* A "chopped" (i.e. very distinctive but uncoded) response is given on a fixed wavelength, namely that of the WS Interrogator type 242 (182 Mc/s.). This condition is for use by an important unit such as the flagship requiring to distinguish herself, or by a ship acting as a datum point. It is observed that, were it not for the wide interrogator beam, condition B would make practicable plan display of I.F.F. since the bearing of the centre of the response would always be correct.
- (iii) *Button I.* Normal Mark III sweep, for use when friendly aircraft require homing and type 251M is not used. The power of the transponder can be reduced at will while in this condition.

78. *Use of morse coding with type 253P.* The present intention is to use morse code groups to distinguish particular ships or units, and these are allocated in S.P. 2576 and 2576A. 79-80.

Radar recognition in submarines. Type 253MW and I.R.T.

81. Type 253MW consists of type 253 adapted for use in Submarines, particularly when co-operating with aircraft. It can be used in three conditions :—

- (i) *Button I.* Normal Mark III sweep, but reduced in power to approximate to the expected location range of a Submarine from a surface ship, in order to preserve security outside this distance.
- (ii) *Button B.* (Beacon.) Coded response on a fixed wavelength, namely that of aircraft ASV (176 mc/s.), in order that the aircraft can determine by radar the relative position of the submarine and a target detected by ASV. Full power is used.
- (iii) *Button K.* (Keyed.) Provided the transponder is being interrogated by ASV the response can be keyed on a fixed wavelength (176 mc/s.) like a W/T transmitter in order to communicate with the aircraft on a wave which, compared to ordinary W/T, is relatively safe.

82. At present submarines do not carry an interrogator, owing to space limitations. A combined Interrogator-Responser-Transponder (I.R.T.) is under development which will give submarines the ability to interrogate, as well as beacon and keying facilities, but normal I.F.F. facilities will then have to be sacrificed. Of the two, interrogation is more important than I.F.F., since a submarine does not usually operate in the same area as friendly ships

83. Fig. 62 illustrates the tactical use of type 253MW buttons B and K.

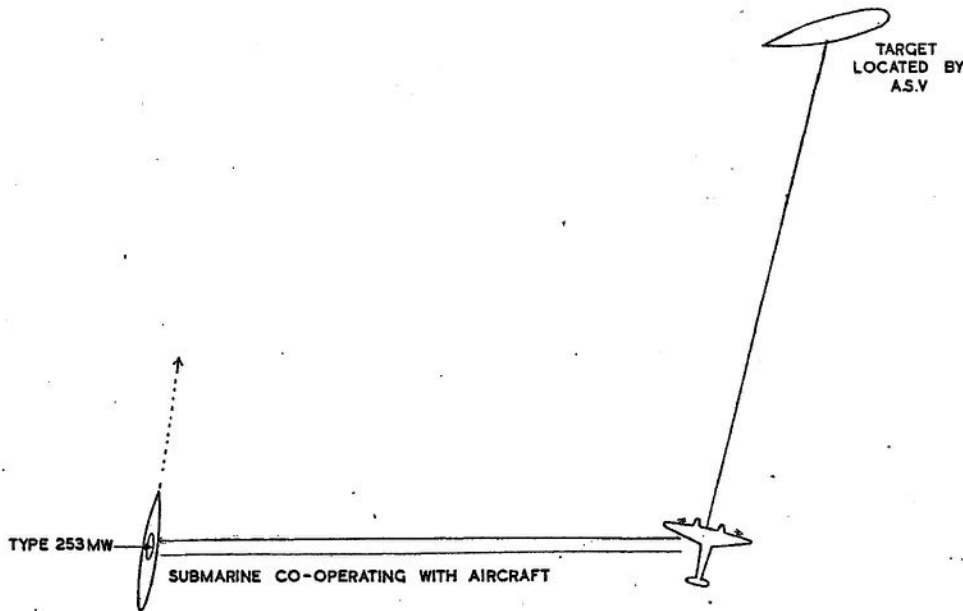


Fig. 62—Operational use of type 253 MW in a submarine co-operating with a reconnaissance aircraft.

Red—Aircraft locates target by A.S.V.

Blue—Aircraft obtains range and bearing of submarine from type 253MW button B (Beacon).

Green—Aircraft passes necessary information to submarine using keyed A.S.V.; submarine answers using button K (keyed) of type 253MW.

84-85.

I.F.F. Mark IIIG and interrogators types 941 and 243Q

86. Fighters are fitted with a special modification of I.F.F. Mark III, known as Mark IIIG. When the fighter is ordered to switch to "G" response the I.F.F. gives short periodic responses on a preset fixed wavelength outside the "A" band in much the same way as type 253P in ships will respond on Button B.

87. The object of this is to provide direct plan display of I.F.F. response on P.P.I. or Skiatron while the radar set is sweeping so that our fighters can be recognised immediately by the F.D.O. Owing to the wide beam of the interrogator, this display would be unsatisfactory without special measures being taken, and the response would appear as in Fig. 63 (a).

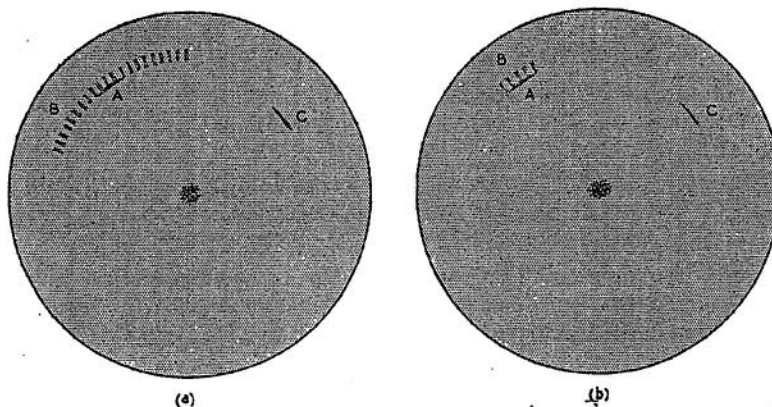


Fig. 63—Display of "G-Band" I.F.F. response on skiatron as it appears (a) without "gating" (b) with "gating."

A—Echo from friendly fighter.
B—"G-Band" I.F.F. response.
C—Echo from another aircraft.

88. In addition, of course, type 243 will only trigger "A-Band" I.F.F. A special G-Band Interrogator type 941 is therefore being fitted to WA type 281BM (and will be fitted to its successor, type 960); to work only on the selected G-Band wavelength. In order to avoid cluttering the display with wide responses, a system known as **gating** is employed. Responses only reach the Skiatron when they are at exactly the same range as the location echo, and will only be shown over the same arc as the location echo. This will result in a false though useful improvement in the apparent bearing discrimination of the Interrogator, as shown in Fig. 63 (b).

89. It is possible for a snag to arise when using "gating," if an enemy aircraft and a friendly are at exactly the same range, and both are within the beam of the interrogator (say, about 70°). In this case the enemy may also appear to show I.F.F. response when the location set is trained on it. The false response will, however, disappear as soon as the ranges of the two aircraft draw apart, as they are almost certain to do.

90. When type 941 is fitted and displaces type 243, an "A" Band Interrogator type 243Q with separately controlled aerals will be fitted in association with type 281BM (or 960).

91.

SEPARATELY CONTROLLED INTERROGATORS, THE CENTRAL INTERROGATING POSITION

92. The difficulties of using on "A" Band I.F.F. with an interrogator which is attached to a sweeping location aerial, as explained in *para. 39*, has led to the use of separately controlled interrogators with sets such as types 281BM, 277 and 293. The system is to employ a sector display panel L43. A 6° sector from the plan display of the location set is selected and all echoes in this sector are shown on the top trace of the sector display, where they persist for a short time. The I.F.F. response or responses in the direction in which the interrogator is pointing are shown below on a second trace, and can thus be related for range with the location echoes. The appearance is, in fact, exactly similar to Fig. 58.

93. This arrangement is at present fitted in the appropriate location radar office. When the Radar Display Room is developed, the various sector displays and Interrogator Aerial Controls will be fitted in the R.D.R. and will form a **Central Interrogating Position**. It may then prove possible to economise in the number of interrogators fitted in a ship.

94-95.

ROTETS

96. Mention should be made of a non-radio recognition device known as a rotet. This consists of a rotating reflector which gives a distinctive rise and fall in echo height when a centimetric set is trained on it. It was used extensively in the direction of coastal force craft by high-powered shore radar sets at a time when the radar recognition system was unable to obtain responses at anything like the location range. In view of its limited application and the development of the higher powered interrogator (type 242M), the rotet system will not become general. It may prove useful, however, in special cases; one of these is the recognition of isolated shore ranging marks (*Chapter XII*) where the fitting of type 253 is impracticable.

97-99

FUTURE DEVELOPMENTS

100. The **Mark IV** system of I.F.F., with associated Interrogators, has been developed in the U.S.A. Under certain circumstances it might be used by British ships co-operating with U.S. forces. It operates on about 60 centimetres.

101-103.

104. The **Mark V** system of I.F.F., with associated Interrogators, is under development for Allied use as an eventual successor to the Mark III system. It will overcome many of the limitations of the Mark III system, particularly as regards security and direct display on P.P.I.

105-109.

U.S. INTERROGATORS

110. The following Mark III system U.S. Interrogators may be met with:—

- | | | | | |
|-----|--------------------------|-----|-------------------------|----------------|
| (a) | A-Band Interrogator type | BL, | for use with U.S. types | SA and SK. |
| (b) | " | " | BM, | " " SM1. |
| (c) | " | " | BN, | " " SG and SL. |
| (d) | G-Band Interrogator type | BO, | " " | SM1. |

111. These Interrogator aerals are either directional and built in to the location set aerial so as to rotate with it (*e.g.* BL), or alternatively are omni-directional.

112. U.S. Interrogator BP is for use with the Mark IV I.F.F. system.

113-115.

RADAR BEACONS

116. As explained in *para. 5*, the object of radar beacons is to provide homing facilities for aircraft, or navigational aid for ships. A radar beacon works on the same principle as I.F.F. It requires to be triggered by an Interrogator or Aircraft's Lucero, or in certain cases is triggered direct by a location radar set. The beacon then responds, usually on the same wavelength, with a morse code or other distinctive signal. Until triggered the beacon does *not* transmit, even if switched on.

117. The bearing accuracy obtained is of the order of 2-5° when a directional interrogator is used. The range accuracy is 200-500 yards, depending on the strength of the response, the stronger response giving the better accuracy; range should therefore be read off when the interrogator is pointing directly at the beacon, and not whilst training right or left to get the bearing.

Radar beacons used for aircraft homing

118. **Radar Beacon Type 251M** is the standard radar beacon for homing aircraft and is fitted in all large ships, a proportion of convoy escorts, and in certain other ships such as Flotilla leaders according to operational requirements.

119. Type 251M is triggered direct by A.S.V. Mark IIN. The Interrogator "Lucero" fitted with later (centimetric) A.S.V. has less power, and to compensate for this, type 251M is being converted to **type 251P** which has greater sensitivity and power. The range obtained depends primarily on the height of the aircraft. Typical ranges are:—

	LUCERO. v. 251P	
	A.S.V. MK. IIN. v. 251M	A.S.V. MK. IIN. v. 251P
Aircraft at 1,500 ft.	50 miles	60 miles
Aircraft at 5,000 ft.	80 miles	100 miles

120. The morse code group for distinguishing the ship or unit in which a beacon is fitted is allocated in S.P. 2560, and is set on each individual beacon. It is changed at intervals.

121. **M.A.B.** Type 251M is also fitted in those fast merchant ships who sail independently and may be provided with air A/S escort. When fitted in a merchant ship the set is called "M.A.B." for security reasons.

122. **I.F.F. Types 253 MW/P used as radar beacons.** Type 251M operates in the centre of the "A"-Band of the recognition system, and therefore it is possible to use the I.F.F. set type 253 as a low-power radar beacon if no type 251M is available, or if it is desired to restrict the beacon range for security reasons. **Type 253** will give ranges to aircraft A.S.V. Mk. IIN of the order of 30-40 miles, depending on the aircraft height, and to aircraft Lucero of the order of 20 miles. With **type 253P** the same ranges will be obtained except when the set is deliberately desensitised to avoid its use by enemy aircraft; in this case the maximum range obtainable is about 15 miles.

123. **Type 253MW** in submarines can be used as a radar beacon as explained in *para. 81*; indeed, this is one of its most important functions.

124. When I.F.F. sets are used as beacons, one of their special codes is generally used to distinguish the particular ship concerned, as explained in *paras. 59* and *60*.

125-126.

127. **U.S. Radar Beacon Type YJ.** Type YJ is a radar beacon fitted in certain aircraft carriers, which will respond either to A.S.V. Mk. IIN or Lucero (on 1½ metres), or to aircraft radar sets using 50 cms. (ASB). It is generally similar to type 251M.

128-129.

Use of radar beacons for homing aircraft to ships

130. Radar Beacons are somewhat more liable to enemy interception than I.F.F. sets because of their greater power and the fact that they remain on a fixed wavelength instead of sweeping a waveband. For this reason they should only be switched on when actually required to home aircraft.

131. On the other hand they provide the most secure method at present known of homing by radio means and, unless enemy aircraft are known to be using precisely the same wavelength, the value of the beacon to our aircraft will usually far outweigh the possible dangers of its use or interception by the enemy.

132. The Senior Officer is responsible for ordering the **Radar Beacon State** for ships in company. This is normally State P (Beacons off). Typical examples for the use of State Q (Beacon switched on continuously, ready to be triggered) are:—

- When homing aircraft, when the beacon should be switched on one hour before the expected time of arrival of the aircraft, and switched off when it arrives provided the visibility is good. (These are the instructions given to Merchant Ships for using M.A.B.)
- To assist escorting aircraft to keep touch.

- (c) When operating with radar-fitted aircraft, for example, when aircraft are sweeping an area in the vicinity.
- (d) When no I.F.F. set is available in ships, and it is necessary to provide recognition, *e.g.* to avoid attack by friendly aircraft.

133. The Senior Officer will also detail a **Radar Beacon Guard**, so that only one ship in a unit will normally switch on her radar beacon. This avoids too many beacon responses appearing and cluttering up the aircraft's A.S.V. trace, and enables the beacon code to be read without confusion. The fact that a Radar Beacon Guard has been detailed does not, however, prohibit other ships switching on their beacons in cases, such as several carriers being in company where aircraft must be able to recognise a particular ship in the unit.

134. The precise rules for the use of Radar Beacons in ships are laid down in *C.B. 04092/44* and amplified in station orders. They are also applicable to type 253 when used as a beacon.

135. Like type 253, Radar Beacons are fitted with an indicating lamp to show when they are being triggered.

136-139.

Radar beacons used for ship navigation

140. Radar beacons are becoming extensively used ashore for navigation in conjunction with surface warning radar sets and their associated interrogators. They are also used afloat, particularly in assault operations to mark important units such as the Senior Officer's ship, or a ship being used as a datum point. Details of performance are given in *Chapter III*.

141. **Type 253S** is an I.F.F. set type 253 fitted ashore, for use with interrogator type 242.

142. **Type 255** is a marker buoy beacon for use with type 291 only.

143. **Type 256** is a shore radar beacon for use with type 291 only. There are also some R.A.F. type "O" Beacons, similar to type 256, which can be used by type 291.

144. **Type 951** is a secure marker beacon for use ashore or afloat in assault operations, and has to be triggered simultaneously by type 970 (or other 10 cm. set) and the associated Lucero or Interrogator.

145. **Type 952** is similar to type 951, but has to be triggered by a 3-centimetre set (*e.g.* type 268) and an associated Interrogator.

146-149.

Radar beacons used for aircraft navigation

150. Type 251M is used ashore to assist aircraft fitted with A.S.V. Mk. IIN or Lucero.

151-152.

Coding, use and control of shore radar beacons

153. Radar beacons used for ship navigation are provided with 3 or more alternative codes. The details of the position, code, operating hours, and controlling authority are laid down in *H.D. 335—Navigational Aids in War* for home waters, and promulgated by Commanders-in-Chief abroad. Operation is usually continuous.

154. Similar details for radar beacons used for aircraft navigation are contained in *S.P. 2558* and *S.P. 2559*.

CHAPTER XV

ENEMY AND BRITISH RADIO COUNTER-MEASURES AND
ANTI-JAMMING MEASURES

1. The term R.C.M. (Radio Counter-measures) has in the past been viewed with some suspicion, perhaps with reason, as cloaking one of the darker forms of black magic. Actually, the subject is not particularly abstruse, and it is certain to come into increasing prominence.

2. There is at present a foreseeable limit to the advance in radar. Thus surface detection is limited to optical range, air warning radar has achieved the object if fighters can be flown off in time to intercept, and accurate gunnery radar is not required outside the range of the gun itself. When both sides have reached these limits, and in the absence of some startling new technical development, they are bound to turn to means of spoiling their adversaries radar by means of "counter-measures" while retaining the use of their own by improving "anti-jamming measures." This will provide another analogy with the race between gun and armour.

3. Alternatively, if the enemy's radar development does not catch up with ours he is even more likely to look around for some quick cheap method (*i.e.* counter-measures) which will nullify our success and restore the tactical balance.

4. It is therefore clear that R.C.M. and A-J are subjects of importance, which must be kept to the forefront. This chapter briefly describes the operational considerations. It is not possible to go more deeply into the subject here partly because much of the technical information is secret and partly because it changes so rapidly. Certain information is contained in C.B. 03067/43—*Enemy Radar*. The rest is likely to continue to be promulgated by Admiralty Letter or Message as information and Intelligence on enemy radar technique becomes available.

5. The sequence of events may be summarised as :—

(a) Intelligence and Interception, which are necessary to discover what radar frequencies are being used. Intelligence is not within the purview of this book.

(b) Counter-measures to spoil radar. These may be "radio" (*e.g.* jamming), or "non-radio" (*e.g.* "window").

(c) Anti-jamming measures, to evade or mitigate the effects of (b).

6. For convenience the following remarks are written primarily on the basis of what we can do against the enemy. They are equally applicable to his possible action against us.

INTERCEPTION AND INTERCEPTION RECEIVERS

7. Before counter-measures can be taken or even developed, it is necessary to discover what radar wavelength or waveband is being used, and interception receivers are used for this purpose. Once the enemy's radar wavelengths have been ascertained, the object of interception receivers becomes :—

(a) To give tactical warning of the approach of enemy ships or aircraft, in order to attack or evade.

(b) To give warning of the moment when the enemy is about to open fire, obtain the exact frequency of his gunnery radar, and so tune and operate jammers to interfere with his radar ranging, bearing and spotting.

8. Although interception receivers do not necessarily lead to the use of counter-measures it is convenient to deal with them here. The outstanding feature is that they *generally* cover a wide waveband in order to be able to intercept a number of known enemy wavelengths and provide against his using new ones. The fact that a wide band is covered reduces efficiency in three ways :—

(a) The sensitivity of the receiver on any particular wave is relatively low.

(b) The fact that the operator has to search over a fairly wide band reduces the average range of interception, since the other ship's radar aerial may not be pointing at the intercepting ship at the moment when the receiver is on the precise wavelength of the radar. Meanwhile, the two ships are closing.

(c) Owing to the wide band covered, a large number of extraneous signals and noises will be heard, some from outside sources and some from own ship's radar or other electrical apparatus. Examination of these will slow up the search and so further reduce the average range of interception, and false alarms will be common.

9. It is for the above reasons that it is recommended, in the table of likely interception ranges in *Chapter V, para. 63*, that *Column 1* should be used in practice when considering interception by the enemy. In fact, the range may be even less than that shown in *Column 1*, when the difficulties of fitting and operating gear afloat are taken into account.

10. On the other hand it is wise to remember that if the enemy decided to go in for interception in a big way, for the reason given in *para. 3*, he could improve results very considerably by fitting and manning a larger number of more efficient receivers each covering a smaller waveband. This might bring the interception range up to the figures shown in *Column 2*, in *Chapter V*, or to *Column 3* under conditions of anomalous propagation.

11. The bearing accuracy obtainable from interception receivers varies considerably and depends primarily on the importance attached to the subject, *i.e.* whether it is considered worth while fitting a complicated rotatable aerial in a clear site—probably at the masthead—at the expense of something which may be considered more useful such as a radar set. Given the best conditions, there is no technical difficulty in obtaining a bearing of any radar transmission to an accuracy of 3° or better. In practice it is unlikely that this will be obtained. With metric wavelength sets (*e.g.* against our WA sets, and 1½ metre WC sets) the accuracy might be 15–30°, or it might only be possible to distinguish between quadrants, or between port and starboard. With decimetric and centimetric sets (*e.g.* against our 50 cm. gunnery sets or our 10 cm. WS and WC sets) the bearing may well be more accurate, perhaps 5°, since a small rotatable reflector could be fitted.

Operation of tactical interception receivers

12. Depending on personnel available, interception receivers should be manned when the enemy may be within range of radar interception under anomalous conditions. When (and if) first intercepted the enemy's warning radar will probably be sweeping. As the range decreases the moment may arrive when his radar detects the intercepting ship. *If P.P.I. is not fitted* this moment will be apparent by the radar beam steadying on own ship, or becoming obviously interested, and this, of course, should be reported at once to the Operations Room. *If P.P.I. is fitted* (which would be apparent from the regularity of the sweep) there may be no indication that the intercepting ship has been detected.

Interception receivers used in conjunction with jamming sets

13. The function of Tactical Interception Receivers is to intercept warning radar. Once contact between forces has been made, whether by radar or visually, it is necessary to prepare to jam the enemy's gunnery radar. This involves finding the exact wavelength in order to tune the jammer, and for this purpose an interception receiver must be closely associated with the jamming set. The receiver may or may not be the same as that used for tactical interception. If a special receiver is fitted, it is usually known as a "monitor" receiver.

14. **Operation.** When the enemy is heard to switch on his gunnery radar, it may be expected that he will shortly open fire. This should be reported at once to the Operations Room. Meanwhile the jammers are tuned to the enemy frequency and operated as explained in *para. 31 et seq.* It is, however, most important to maintain watch on the Interception receiver, interrupting the jamming for brief periods if necessary, in order to observe and follow any evasive shift in wavelength made by the enemy.

15. During this phase all the radar sets in own ship will be in operation, and their harmonics may interfere with the operation of the interception receiver unless care has been taken to identify them beforehand.

Types of interception receivers

16. **British receivers.** Outfit FV1 (or QV4 when fitted in submarines) covering 50–150 cms. and giving quadrantal bearing, has been the standard British interception receiver afloat. It is being replaced by a series of new receivers covering a wider total waveband.

17. **Enemy receivers.** A list of German search receivers (G.S.R.) will be found in *C.B. 03122B (S.N.I.P. 81/44)*. U-boats now carry receivers covering:—

(i) 120–180 cms. with automatic scanning, visual presentation and an all-round looking aerial. This band covers ASV Mark IIN and WC type 291.

(ii) 8–12 cms. with a directional aerial and headphone or loudspeaker reception. This band covers centimetric ASV, and types 271/3, 274, 275, 276, 277 and 293.

18. The 120–180 cm. receiver is thought to be a good and efficient receiver, but even so it is believed that the average range achieved against ASV Mark IIN is only of the order of 15 miles. This shows the considerable difference between the theoretical range obtainable and the sort of range obtained under operational conditions. The early type of 10 cm. receiver had a low-gain aerial and it is most unlikely that under the best conditions its range exceeded 5 miles. The present model, however, has a horizontal cylindrical reflector giving increased aerial gain, and may give warning at about 10 miles. It will be observed that once again this figure falls far short of the theoretically possible interception range:

19–24.

COUNTER-MEASURES

25. Once the enemy's radar wavelength is known counter-measures can be taken. These may be:—

- (a) Radio Counter-measures, *e.g.* jamming;
- or (b) non-radio counter-measures, *e.g.* "window."

Radio Counter-measures

Jamming

26. Shipborne jamming is usually confined to attempting to spoil the enemy's gunnery radar ranging, bearing, and spotting, *i.e.* deny him blind gunfire facilities. It might, however, be extended to jamming warning radar in order to prevent the accurate tracking which is required for fighter direction and torpedo control.

27. The disadvantages of jamming warning radar are :—

(a) It discloses the presence of the jamming ship, who may not have been located by the opposing radar.

(b) Although it stops the enemy ranging, it provides a good bearing of the jammer.

(c) Except at close range a radar set is only jammed when it is pointing at the jammer. In order to mask a whole unit completely several ships must be fitted with jammers to cover all the enemy radar wavelengths in use. This is often impracticable under normal circumstances.

28. In spite of these disadvantages tactical jamming may be used in certain circumstances, such as an assault when it is vital to conceal the strength and disposition of the invading force ; and widespread jamming was in fact used in the 1944 invasion operations. Nice judgment is required to avoid jamming unnecessarily soon, *i.e.* before the force might otherwise be located by radar and other means.

29. Airborne jamming is comparatively common, and is usually directed against G.C.I. (Ground Control of Interception) or S.L.C. (Searchlight Control) radar sets.

30. Typical effects of jamming on "A" display and P.P.I. are illustrated in *Fig. 64*.

31. **Operation of jamming sets against enemy gunnery radar.** Type 91 is the jamming set fitted in Battleships and Cruisers, although it may be superseded (*e.g.* by type TDY), or additional jammers may be provided in future, its operation will be described as being typical.

32. The ideal procedure is to pick up the enemy's radar on the Interception receiver, and then tune type 91 to this wavelength, interrupting the jamming for brief intervals to check that the enemy has not altered his wavelength.

33. The above procedure sounds simple. In fact it is far from easy owing to various technical difficulties, and interference received from radar sets in own unit. It is imperative therefore that every opportunity should be taken of practising jamming during exercises, particularly when it is remembered how few opportunities may occur to test the organisation in action. The inclusion of jamming as a normal part of firing exercises will also emphasise the serious effect it may have on gunnery, and ensure that all possible anti-jamming measures have been thought out.

34. The correct moment to jam enemy gunnery radar requires judgment. If it is done too soon it may enable the enemy to put his anti-jamming measures into operation in time to regain the radar "initiative." The ideal is, of course, to start jamming just before the enemy opens fire. In practice the moment is likely to be delayed until the enemy's first salvo, when jamming should be started without further orders.

35. **Barrage jamming.** Owing to the difficulties of operating the Interception receiver it is quite possible that the enemy's gunnery radar will not be picked up at all. In this case the jamming set should be switched on as soon as the enemy opens fire, being set in advance to the believed enemy wavelength. It cannot do any harm and may well do good (it is believed that "Duke of York" interfered effectively with SCHARNHORST in this manner). If there are two or more ships, the jamming sets should be mutually staggered in wavelength so as to cover as wide a band as possible around the believed enemy wavelength, thus putting up a radio "barrage."

36-39.

40. **Shore jamming.** Remarks on jamming would be incomplete without a mention of the Dover Straits, where jamming of radar first came into prominence. When the Germans started using radar for accurate radar blind-fire the passage of our Convoys through the Straits was seriously threatened. It was as a reply that type 91 was first developed. Large numbers had to be fitted along the coast, so as to cover each sector as viewed from each enemy radar station. Later the Germans retaliated by increasing the number of radar sets and using different wavelengths, necessitating more and more jammers on our part, and so the race proceeded with our side usually managing to keep abreast and sometimes ahead.

41. Similar occasions might arise in future if it was required to cover a strait against enemy fire using radar, or possibly to cover a prominent shore mark against radar ranging by bombarding ships.

Other radio counter-measures

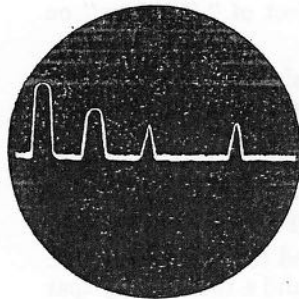
42. Other radio counter-measures have also been developed. These include methods of falsifying radar range and bearing and/or creating false echoes.

43-44.

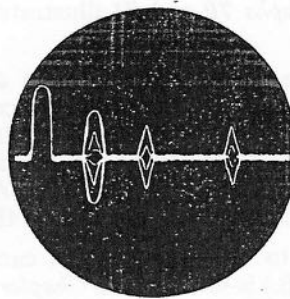
Non-radio counter-measures

45. Non-radio counter-measures make use of reflectors which confuse the display either by providing a few false echoes or by "infecting" a whole area.

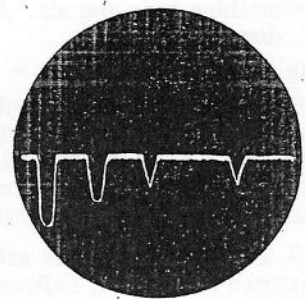
46. **Window.** Window consists of strips of tinfoil or paper backed with tinfoil cut to half the wavelength of the radar to be jammed, so acting as good reflectors. Bundles of these strips are dropped from aircraft and "infect" an area which may be many miles deep and wide, depending on the amount of window dropped and the beam width and range discrimination of the radar being "jammed."



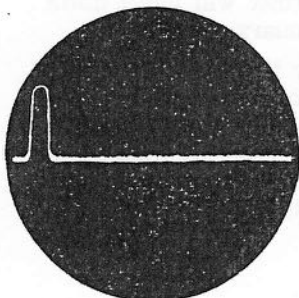
NORMAL PICTURE



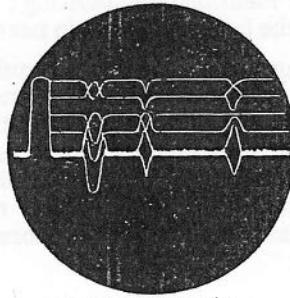
BEATING ECHOES



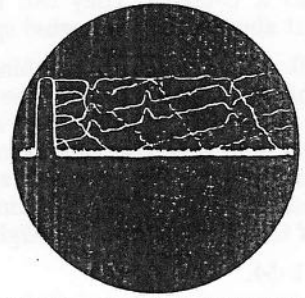
INVERTED ECHOES



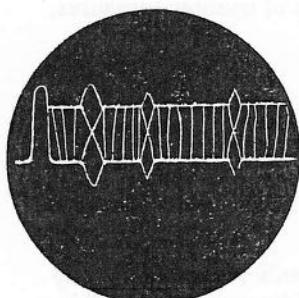
CLEAN TRACE



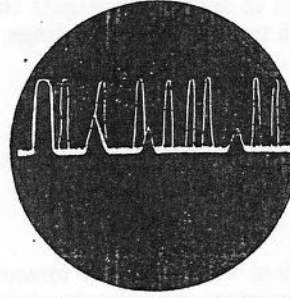
TRAM LINES



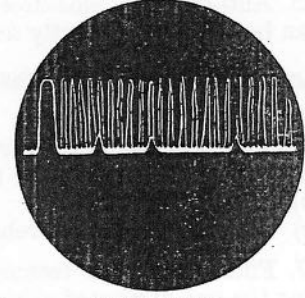
CRISS-CROSS PATTERN



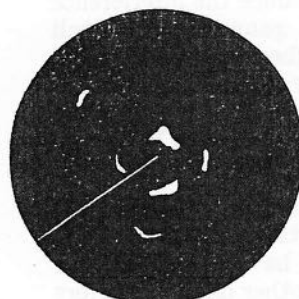
DOUBLE ECHOES



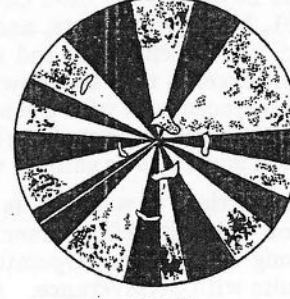
TELEGRAPH POLES



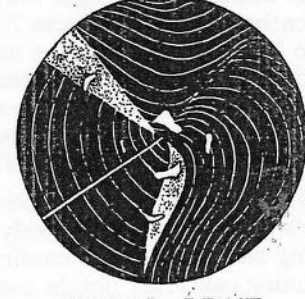
RAILINGS



NORMAL P.P.I. PICTURE



STAR



FINGER PRINT

FIG. 64. TYPICAL EFFECTS OF JAMMING AND RADIO INTERFERENCE ON RADAR DISPLAYS.

47. The strips float gradually to earth (or sea), moving, of course, with the wind, and the area often remains infected for 15-30 minutes. The appearance on P.P.I. is that of rather indeterminate land echoes, and it is difficult and often impossible to follow the movements of aircraft within or behind the infected area. "Window" is used to prevent the use of radar for fighter direction, gunnery, and searchlight control, and its appearance should be a warning that something is in the air. *Photographs 70 and 71* illustrate the effect of "Window" on P.P.I. display.

48. Naturally "window" is more effective ashore than at sea, since shore radar sets cannot steam away from it; but the possibility of its use by aircraft at sea cannot be excluded. It is also possible to lay it from shells fired so that the "window" echo upsets the enemy's radar bearing accuracy, particularly if beam-switching is being used; and it will also interfere with radar ranging should the window and ship echoes merge. Alternatively, it might be used to plant false echoes similar to those of large ships, and so trap the enemy into a tactical error.

49. **Decoys.** Reflectors attached to balloons or spars can be used to cause deception. The German radar decoy balloon (R.D.B.) is described in *Chapter VIII*, and a radar decoy spar (R.D.S.) has also been used with the object of making our aircraft and ships waste effort by investigating or attacking false contacts. The R.D.B. and R.D.S. aim at giving the same sized echo as a U-boat. They can best be identified by plotting; the former will move down wind at about two-thirds wind speed; the latter will remain nearly stationary.

50. Large ships approaching enemy coast have been simulated by the use of reflectors attached to towed balloons, the height of the balloon and characteristics of the enemy radar being taken into account to give the appropriate "first detection" range and size of echo. Balloon reflectors have also been used to mask bombarding ships against blind fire from shore batteries by upsetting bearing accuracy and possibly ranging also. The procedure is for the ship and balloons to keep within the beam width of the enemy radar set, with the ship to one side of the balloons and at a slightly greater range from the shore.

51-54.

ANTI-JAMMING

55. Anti-jamming measures are used to defeat or mitigate the effects of counter-measures, and can be most conveniently dealt with under similar headings.

A-J against radio counter-measures

Against jamming

56. The measures in the reverse order of their likely success, include:—

- (a) Technical devices such as filters.
- (b) Shifting wavelength.
- (c) Use of a different waveband.

57. **Filters** and other technical devices which cut out unwanted signals without seriously reducing the size of wanted echoes can compete with the simpler forms of jamming, and will be fitted in new radar sets and retrospectively in some old ones.

58. **Shifting wavelength** may have to be tried if the filter does not reduce the interference sufficiently. With WA types 79 and 281, 1½ metre WC sets, and 50 cm. gunnery sets a small change in wavelength can be made and may be effective, and should therefore be exercised from time to time. If the extent of shift exceeds that laid down in the technical handbooks and C.B. 4212 the range will be seriously reduced, and with gunnery sets the bearing accuracy spoilt; this limitation must be balanced against the extent of the interference. With WA types 79B and 281B and centimetric WS, WC and gunnery sets shifting wavelength is not practicable.

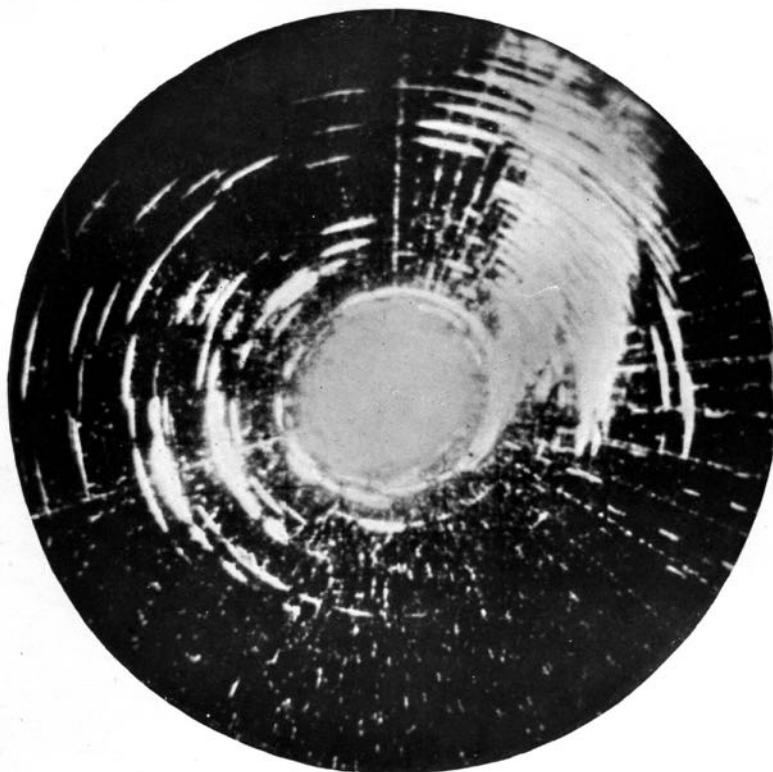
59. It should be remembered that shifting wavelength is an acknowledgment of the enemy's success, and he is likely to follow suit with his jammer. Efforts to see through the jamming should therefore continue as long as possible. Operators who have had experience of jamming can often obtain usable results with perseverance. On the other hand, operators who have never even been exercised against our own jammers are likely to give up at once; this is another good reason for carrying out jamming exercises.

60. **Use of a different waveband.** It is unlikely that more than one waveband will be jammed at the same time, so an obvious counter is to use a radar set in a different waveband to that being jammed, accepting the loss of efficiency and inconvenience involved. For example:—

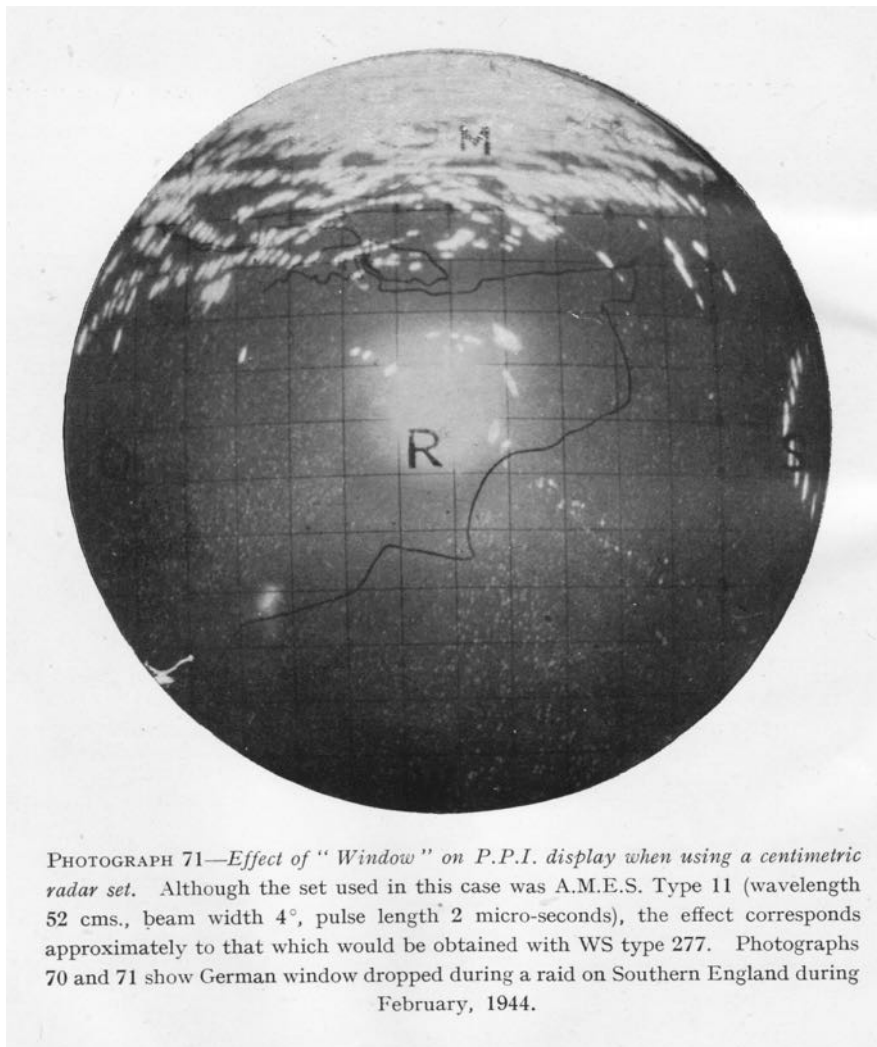
(a) Big ships are likely to have a selection of gunnery sets in the 10 cm. and 50 cm. band to choose from.

(b) WS and WC sets, and WA type 281/B if still fitted with a ranging tube, can range, with fair accuracy if it is acceptable to give up their sweep and therefore their warning function. In new WS and WC sets ranging can be carried out without stopping the sweep, by the use of Sector Display Panels.

(c) Gunnery sets can be used for surface warning and limited air warning.



PHOTOGRAPH 70—Effect of "Window" on P.P.I. display when using a metric radar set. The set used was G.C.I. Fixed type (wavelength 1.45 metres, beam width 15° , pulse length 4 micro seconds). With WA type 281 the echoes would be at least twice as wide, and deeper, and to the north-east nearly twice as great an area would be "infected."



PHOTOGRAPH 71—Effect of "Window" on P.P.I. display when using a centimetric radar set. Although the set used in this case was A.M.E.S. Type 11 (wavelength 52 cms., beam width 4° , pulse length 2 micro-seconds), the effect corresponds approximately to that which would be obtained with WS type 277. Photographs 70 and 71 show German window dropped during a raid on Southern England during February, 1944.

61. An organisation should therefore be worked out in each ship, and practised, to compete with the jamming of one waveband or type of set. It is largely a matter of internal communications and drill, and is therefore almost sure to fail if it is tried for the first time in action.

62. Where several sets are fitted using different wavelengths in the same waveband, such as types 274 and 275, it will be advisable to keep them all switched on and trained on the enemy, even if they are not all actually required (types 277 and 293 will, of course, also be on, but will be sweeping). This procedure may well confuse the enemy, since he may, for example, try to jam type 275 instead of type 274 during a surface action. The same argument applies to the 50 cms. gunnery sets; even though the optimum wavelength is the same for all sets, there are slight differences in practice.

Against other radio counter-measures

63. Against other radio counter-measures a possible defence is to examine the situation with one or more other radar sets using different wavelengths. If the extra echoes are proved to be false they can be neglected and only the nearest echo tracked.

A-J against non-radio counter-measures

64. **Against Window.** There is no complete counter to "window," but its efficiency is less against radar sets whose wavelength differs from that for which the strips are cut, particularly when the radar wavelength is greater. Thus type 79 is less likely to be affected than type 281. Although centimetric sets may be affected by window cut to a longer wavelength, their narrow beam and good range discrimination generally has the effect of localising the infected area and may enable a target to be tracked through it. Type 277 should, therefore, be used to investigate an infected area, as recommended in *Chapter X*, the aerial being elevated as necessary.

65. **Against decoys.** The appearance of the echo may help to classify a decoy, but it will usually be necessary to confirm this by plotting, *vide para. 49*.

66-69.

PERSONNEL

70. Hitherto jamming sets and their associated interception receivers have been manned by the radar branch, while other interception receivers have usually been manned by the communications branch. In future they will all be manned by the communications branch (Telegraphists (S) (N).)

CHAPTER XVI

SHORE RADAR

Shore radar is an inter-service concern, and the Navy has considerable interests and certain responsibilities which require study, particularly when planning a seaborne assault. Assuming a successful landing, it is still necessary to protect shipping against air attack in harbour, or E-boat and U-boat attack in the approaches, and this cannot be achieved if the capabilities and limitation of shore radar are unknown to the Staff Officers concerned. Similar facilities are of course required for established bases but in general these have by now been adequately provided as far as the U.K. and Mediterranean are concerned.

FUNCTIONS

2. Shore radar services embrace radar equipment capable of performing one or more of the following functions :—

- (a) Detection and tracking of high and/or low flying aircraft (air cover).
- (b) Detection and tracking of ships (surface cover).
- (c) Control of air interceptions.
- (d) Control of surface interceptions.

RESPONSIBILITIES

3. For these functions, a large number of different types of sets have been produced and/or manned by the three services, and this together with the fact that many sets have been employed in a dual function (e.g., (a) and (b) above) has in the past led to a certain amount of confusion as to responsibilities. The responsibilities for production and manning have now been defined as follows and are laid down in detail in C.A.F.O.'s :—

- (a) **R.A.F.** For *all* approved requirements in any area in which there is an Air Defence Commitment involving the R.A.F. in provision of fighter aircraft.
- (b) **Army.** In areas where there is no commitment for an R.A.F. air warning system, to meet requirements for :—
 - (i) Surface cover, including cover for surface interceptions, for ports and anchorages defended by coast artillery.
 - (ii) Air Cover in conjunction with A.A. Artillery in gun defended areas.
- (c) **R.N.** Surface cover and control of surface interception and air cover for use with squadrons of naval aircraft landed temporarily in an area not covered by (a) and/or (b).

4. This means that the R.A.F. will often *provide and man* the radar required. However, no matter who provides it, it is invariably placed at the disposal of the theatre or area Commander-in-Chief, and used as necessary for the benefit of all services requiring it. Thus, a set provided by the R.A.F. for the dual function of low aircraft cover and surface cover would feed the Army through the appropriate Gun Operations room and the Navy through the appropriate Naval Plotting Room.

PARTICULAR NAVAL INTERESTS

5. Apart from the obvious requirement of air warning so that ships in harbour or near land may be brought to readiness and join in A.A. fire, the Navy's particular interests lie in :—

- (a) General Surface Warning, especially in a strait, in order to deploy forces to cut off the enemy, or to warn ships in harbour of impending attack (e.g., by E-boat or Human Torpedo).
- (b) Detailed surface information in order to carry out radar controlled interceptions of enemy merchant ships or warships (including E-boats and U-boats) by destroyers, Coastal force craft or A/S vessels.

6. Clearly the type of set required corresponds to the WS set afloat, and some typical naval developed sets are described below. There are, however, a considerable number of other suitable R.A.F. ("A.M.E.S.") sets or U.S. sets which may be met with.

TYPICAL SHORE RADAR SETS

7. Sets fall into two categories :—

- (a) Mobile sets, given the suffix T (Transportable).
- (b) Fixed sets, given the suffix S (Shore).

Type 277T (also known as A.M.E.S. Type 57, or Type 14 Mk. II). (*Photograph 16*)

8. Type 277T is a trailer set using similar panels to the shipborne WS set type 277, but with a larger aerial to give greater range and better bearing accuracy and discrimination.

9. The transmitter is contained in one trailer (weight 7 tons) with the aerial mounted on top. To obtain bearing, the whole cabin is rotated by hand. Two further trailers (weight 6½ tons each) are required to provide power, and a "Matador" or equivalent towing vehicle with a generator mounted on it is required to tow the type 277T. A further generator on a trailer (weight 4 tons) is provided as a standby.

10. Results depend upon the height of the site selected. From a 200-ft. site, a large M.T.B. can be detected to 35,000 yds. and a "Hunt" class destroyer to 51,000 yds. Low and medium aircraft can be detected to 80 miles, very low aircraft to slightly over the optical horizon. All these results may, of course, be exceeded under conditions of anomalous propagation.

11. Range accuracy is 200 yds. up to 10,000 yds., range discrimination 400 yds. Bearing accuracy is 2° with bearing discrimination $1\frac{1}{2}^\circ$ on "A" display.

12. Both P.P.I. and "A" display are provided. The P.P.I. should be marked in grid co-ordinates and is used when sweeping and for plotting. The "A" display is used for counting or identifying targets.

13. Lack of power training tends to limit the capability of the set for low aircraft detection, since targets can be missed during the slow sweep and also if many stops are made for counting or identifying surface targets.

14. Interrogator type 242 is fitted and a large interrogating aerial is under development in order to give better range and bearing of I.F.F. responses.

15. A local plotting room is provided in one of the trailers, together with the necessary communications (W/T or R/T) to the Naval Plotting Room.

16. The crew consists of a total of 19 ratings, usually with an officer in charge. The large number is accounted for by the fact that the crew have to be self supporting, usually in an isolated position.

17. This set will be superseded by A.M.E.S., Type 14, Mks. III and IV, which are lorry-mounted equipments incorporating type 277 panels.

Type 277S (also known as A.M.E.S. Type 50). (Photograph 17)

18. Type 277S is similar to type 277T in performance but is a fixed set used in established Coastal areas. The equipment is contained in a brick or concrete structure.

19. The aerial is power operated, which increases reliability of detection of low aircraft, but hand training using "A" display ("inching") can be used.

20. Communications to the Naval Plotting Room are usually by telephone, with a W/T or R/T standby.

21-29.

Other Sets

30. Earlier Naval WS sets have also been modified and used as fixed or transportable sets. Examples:—

AIR MINISTRY TITLE
A.M.E.S. 37
A.M.E.S. 41
—

ARMY TITLE
C.D. No. 1 Mk. IV
C.D. No. 1 Mk. V*
—

BASIC NAVAL SET
Type 271P
Type 271Q
Type 273QS

(Photographs 17 and 18)

31. In addition, as stated, there are a large number of R.A.F. and U.S. types which may be met with. Operational details of those in service are contained in a summary of "Shore Radar Services" which has been prepared under the direction of the Radar Board and will be issued as an Air Ministry publication to authorities (including planning staffs) concerned.

POINTS TO REMEMBER ABOUT SHORE RADAR

Plotting and Communications

32. The information provided by shore radar will be wasted unless efficient communications, plotting, and filtering are also provided. This applies particularly to aircraft detection (a fast aircraft closes 6 miles in 60 seconds).

33. This may seem rather obvious but it is worth stressing as in fact there have been numerous cases where complaints directed against "Shore Radar" have been traced to poor (or even almost non-existent) communications and plotting, which are not strictly radar commitments at all. It is essential, therefore, that these points should receive thorough consideration in the planning stage.

34. Direct telephone communication links to the Naval Plotting Room are the ideal, but W/T or R/T may often have to be accepted in the early stages after landing.

35. The Naval Plotting Room stands in the same relation to its shore radar sets as does the Operations Room to the WS set afloat (*Chapter VI*). Besides filtering radar tracks, passing information to the Fleet (and possibly other services), and conducting controlled Interceptions, the Plotting Room must give all orders to shore radar sets for switching on, type and rate of sweep, and orders to watch, interrogate, hold or disregard targets.

36. The Plotting Room should also give as much general information as possible to the radar sets, including advance information about expected movements. This will enable the radar operators to carry out their job more intelligently, e.g., know which are the most important targets to report first, and will enable the local plotters to carry out a certain amount of useful pre-filtering which will relieve the pressure on the main plotting room.

Siting

37. The projected site for a shore radar set should receive careful consideration, and the site should be changed subsequently if found technically unsatisfactory. Land echoes are certain to be experienced, but if the site is well chosen, satisfactory operational efficiency should be possible over 120°. The blanked arcs must, of course, be known to the Naval Plotting Room.

38. Subject to the considerations of land echoes the site chosen should usually be as high as possible, in order to get best range. This will have the result of causing a blank area at distances up to 5 miles or more owing to wave clutter and the fact that the beam is nearly horizontal. In special cases, therefore, where cover is required at close range it may be better to site the set low down, or use two sets.

The Crew

39. Attention should be given to the comfort of the crew, provision of adequate transport and messing facilities, etc., bearing in mind the isolated conditions under which they often work (*vide Photograph 80*). In exceptional conditions of heat or cold, it is the practice to provide two crews in order to allow for periodical relief.

Dual purpose sets

40. As stated in *para. 4*, many shore radar sets have a dual function, and this may lead to difficulties. A typical instance is a set which provides information for both low air cover and controlled surface interception. The former demands continuous rotation and P.P.I. display, the latter often necessitates stopping at intervals to count and interrogate targets ("inching"). It will usually be necessary for the Area Commander to resolve these differences, e.g., by laying down that the sweep may be stopped for, say, more than 20 seconds in every two minutes but not for a longer period.

Planning

41. Staff Officers planning a seaborne assault are advised to bear the foregoing remarks in mind. It will also be necessary to decide on the correct time at which shore sets should be landed. This will usually be as soon as possible (in the 1944 Invasion operations, they were landed on D+1), but the time of landing of the associated communications and plots, and the availability of ships to provide temporary radar cover, will influence the decision.

42.-49.

SHORE RADAR SETS IN WHICH THE R.N. IS NOT DIRECTLY INTERESTED

50. In addition to the types mentioned, there are many forms of shore radar in whose provision and manning the R.N. is not normally directly interested except possibly in the case of R.N. Air Stations. The information received from these sets is, however, often of acute interest. Typical sets are :—

R.A.F.

- (a) **High and medium air cover.** Long range cover is provided by Chain Stations around the coast. (CH—Chain Home, CO—Chain Overseas) or by mobile stations (MRU—Mobile Radar Unit). **Light warning sets** are also used to provide limited warning particularly in assault operations until heavier equipment can be installed.
- (b) **Medium and low air cover** is provided by a similar chain (CHL—Chain Home Low, COL—Chain Overseas Low, working in conjunction with (a)).
- (c) **Low and very low air cover** is provided by high powered centimetric sets such as A.M.E.S. Type 50 previously described.
- (d) **Fighter Interception** is carried out by GCI stations (Ground Control of Interception) which need careful siting especially when inland.
- (e) **Heightfinding** is an easier problem ashore than afloat and with (a), (b) and (d) above is solved by having two sets of aerials, one high and one low, and comparing the relative heights of echoes received by each. Narrow beam heightfinders are also used, e.g., CMH (Centimetre heightfinder) now called A.M.E.S. Type 13, Mark II.
- (f) **Ground control of approach** is exercised by GCA equipment which controls aircraft down the narrow beam of a centimetric radar set.
- (g)
- (h)

Army

- (j) **Gun Control** including blind fire radar facilities are provided by GL (Gun Laying) sets. GL Marks I and II are metric sets. GL Mark III is a centimetric set comparable to GA Type 275 and requires to be "put on" by a metric GL set.
- (k) **Searchlight Control** by radar is provided by SLC sets mounted on the searchlight.

CHAPTER XVII

COMBINED OPERATIONS AND PLANNING

1. Radar and other types of radio equipment play an indispensable part in assault operations. Though the principles of the use of radar are no different from those described in previous chapters, there are a number of special points which must be borne in mind when planning combined operations. These are:—

- (a) the requirement for great precision and reliability in navigation, in order to make sure of reaching the desired objective;
- (b) the need for special security (radar silence) until surprise is lost;
- (c) the employment of R.C.M., often on a large scale, to mislead the enemy about the composition and position of the assault forces, and later to spoil radar controlled fire from shore batteries;
- (d) the large numbers of ships and aircraft operating in a restricted area, which complicates the provision and control of surface and air cover;
- (e) the necessity for careful organisation of communications, radar, and R.C.M. wavelengths to avoid mutual interference.

2. Both in the planning and execution stages co-operation with other services is required, particularly as regards (d) and (e) above and the policy for using interrogators and I.F.F.

3. The following notes take into account the experience at Anzio and in the 1944 Channel Operations (operation "NEPTUNE") and assume that provision must be made against attack by enemy aircraft, E-boats and U-boats.

MUTUAL INTERFERENCE

4. An Inter-service Mutual Interference Committee will be necessary in order to segregate the many communication, radar, and R.C.M. radio wavelengths involved. Known enemy wavelengths, and the extent of the enemy's Y services, must also be taken into account.

5. The value of "window" used by own forces must be balanced against the interference it is likely to cause against own radar.

6. Arrangements should be made to have wavemeters recalibrated shortly before the operation, as they are frequently found to be considerably in error.

7. Instructions should be given that R/T should be switched off when not required, to reduce interference from the carrier wave.

8. Warning radar sets may require special "A-J" filters to reduce interference from other friendly radio transmissions.

RECOGNITION AND IDENTIFICATION

9. When large numbers of ships and aircraft are operating in proximity the indiscriminate use of Interrogators and I.F.F. would overload the radar recognition system and make it practically useless, for the reasons given in *Chapter XIV*. It will, therefore, be necessary to "ration" the use of Interrogators and I.F.F. For example, in a very large operation the following instructions would be desirable:—

- (a) *Interrogators* to be reduced in power and only to be used by one ship in each unit, and by control ships.
- (b) *I.F.F.* normally to be used only by—
 - (i) ships;
 - (ii) aircraft in distress;
 - (iii) aircraft co-operating with ships;
 - (iv) night fighters.

10. Even so, the radar recognition system is likely to be less reliable than usual, owing to cluttering of displays and the difficulty of quickly relating location echoes and I.F.F. responses. Recognition must therefore be amplified by—

- (a) observing the direction of approach of echoes, *i.e.*, whether from enemy or friendly territory, and whether the track suggests hostile intent;
- (b) a Movements Liaison System, *i.e.*, promulgation of the movements of friendly aircraft. As such signals must be made in a secure code or cypher this information will usually only be available in control ships, owing to the labour involved;
- (c) Y information can often establish the identity of an aircraft where other systems fail.

11. As an alternative to the rationing of I.F.F. by types of craft, it might be practicable to ration it by areas. This has not however been tried in practice, and the long range of aircraft I.F.F. (100 miles or more) militates against it.

SECURITY

12. In normal sea operations it is recommended (*Chapter XIX*) that radar should be used when the balance between its advantages and possible dangers is delicate. In assault operations, however, it may be wise to attach rather more importance to the interception danger until surprise is lost. Much will depend on the knowledge that is available of the enemy's Y Service in the area concerned.

13. Whatever instructions are issued it should of course be left open to Force and Group Commanders to use their judgment in breaking or relaxing radar silence; and the value of intermittent radar transmission for station keeping and navigation must be borne in mind.

RADIO COUNTERMEASURES (R.C.M.)

14. Assuming that the enemy has shore radar in the area of the assault, extensive radio countermeasures will be necessary with the objects of:—

- (a) Avoiding detection of specific units, and so misleading the enemy about the composition and position of the main assault force.
- (b) Creating diversions.
- (c) In the late stages, spoiling radar controlled fire from shore batteries.

15. With regard to (a) and (b) (*para. 14*) a large number of devices may be used, including—

- (a) jamming;
- (b) window;
- (c) reflector balloons;
- (d) various W/T ruses.

16. **Jamming** will have to be carried out on a wide enough scale to prevent useful D/F bearings being taken of the true area of assault, and must of course cover all enemy radar wave-bands. As an example, in operation "NEPTUNE" 700 jammers were used to cover 3 enemy wave-bands on a 30 mile front and even this was only about half the number that was theoretically required. Clearly the fitting of jammers in ships and training of personnel will present a large problem.

17. The correct moment to start jamming will require nice judgment, as otherwise surprise may be lost (unless the enemy has been trained to associate widespread jamming with impending air attack). Generally it should be started shortly before the leading units come within radar detection range from the shore. In assessing this range the possible effect of anomalous conditions must be remembered, and in this connection the experience and knowledge of our own shore radar stations will help.

18. **Window** may be used to confuse the shore defences, or alternatively to simulate ships. In the latter case it should be dropped or fired so as to give the appearance, above the jamming, of an echo approaching at likely ship speeds.

19. **Towed balloons** may also be used to simulate the approach of large ships.

20. At subsequent stages jamming may again be required in selected areas to protect bombarding ships. The extent and duration of this jamming should be planned and controlled by the Force Commander and not left to private enterprise. In addition moored balloons may be used to provide protective "shadow areas" for bombarding ships as described in *Chapter XV*.

EFFECT OF ENEMY R.C.M.

21. The possible effect of enemy R.C.M. must be borne in mind. Where possible, alternative wavelengths or methods should be available. This applies particularly in the case of navigational aids where reliance on one method alone is clearly inadvisable.

SHORE RADAR (*see also Chapter XVI*)

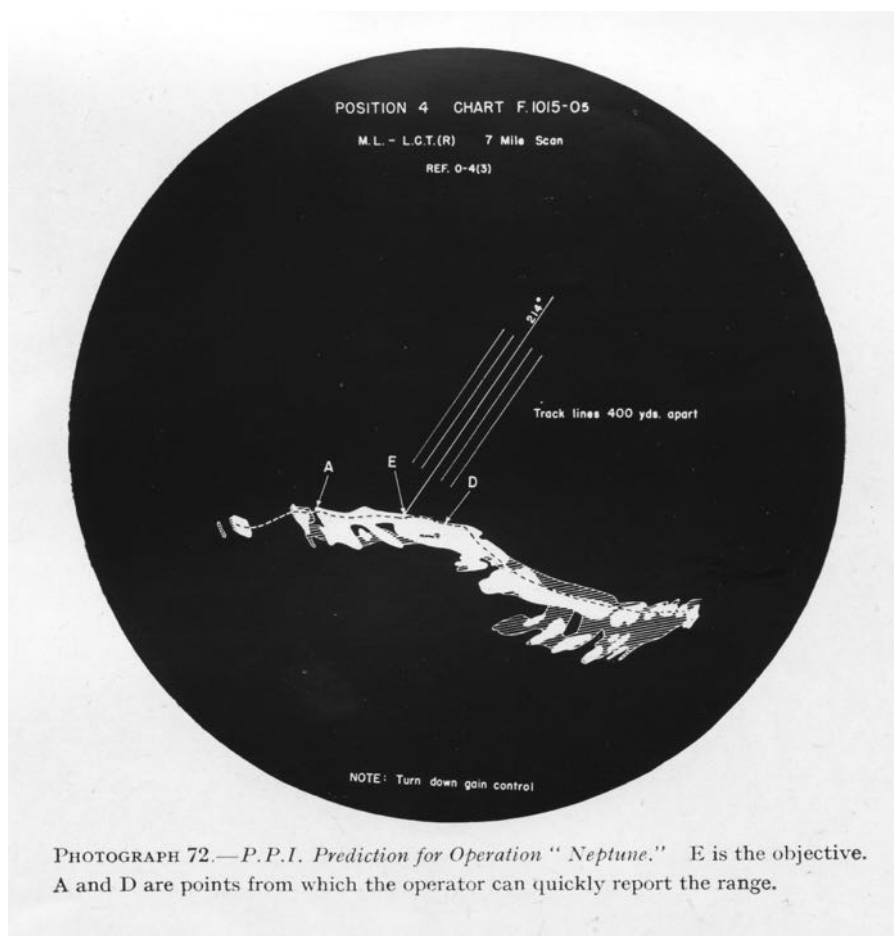
22. Apart from G.C.I. and L.W. warning equipment, shore radar of the type 277T (Transportable) type will be required to be landed at an early stage of the operation to provide surface and low aircraft cover, and arrangements for loading will have to be made accordingly.

23. These shore stations must be sited as favourably as practicable, *i.e.*, high up and with the clearest possible arc, and should be allowed latitude to change their position in order to reduce permanent land echoes. Sandbags or other splinter protection should be provided as well as facilities for living in an isolated position.

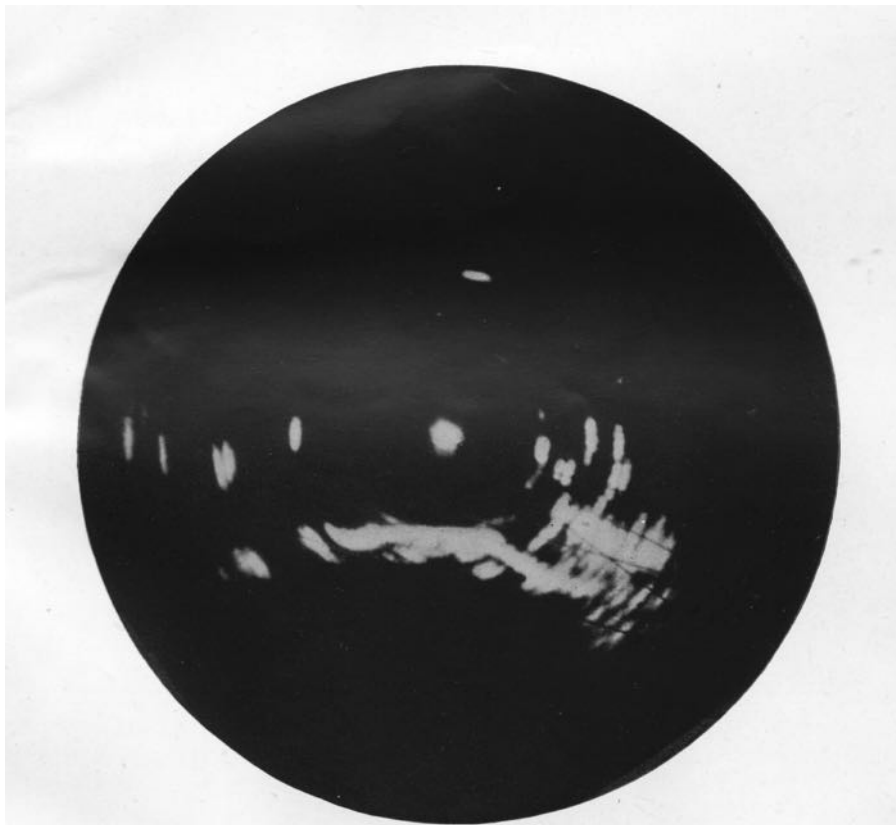
24. At the outset these stations will usually make reports by W/T or R/T to the surface radar controlling ship, using naval methods. Later they will report to the Sector Operations Room Plot, when established ashore, using L/T if possible or alternatively R/T or W/T and the shore station "Radar Tracking Code."

25. It is essential that planning and staff officers concerned should appreciate the capabilities of shore radar stations (*vide Chapter XVI*) and ensure that adequate communications, plotting and control arrangements are provided. It is necessary to emphasise these points as experience has shown that the value of shore radar, which has been perfectly sound technically, has frequently been wasted in the past and defence of the anchorage has suffered accordingly. The working up period must also include practice in the associated communications and plotting without which shore radar is valueless.

26. Once established, shore stations should be kept informed of the tactical and defence situation in order to assist them in the identification and priority reporting of hostile or suspicious targets.



PHOTOGRAPH 72.—*P.P.I. Prediction for Operation "Neptune."* E is the objective. A and D are points from which the operator can quickly report the range.



PHOTOGRAPH 73—*P.P.I. view actually obtained* subsequently, for comparison with the prediction in photograph 72. The coastline to the eastward is somewhat obscured by echoes (including side echoes) from landing craft. Other landing craft may be seen to seaward.

27. When performing a dual role it has been found advantageous, in the absence of power training, to carry out alternate fast and slow sweeps for low aircraft and surface targets respectively. When required to track individual ships it may be necessary to hold the target on "A" display and temporarily give up P.P.I. display and low air cover.

NAVIGATIONAL AIDS

28. A variety of radio aids to navigation are now available and two or more should normally be made used to guard against failure or enemy R.C.M. In all cases previous training is necessary: this applies particularly to the use of WS radar and P.P.I. for beach finding (*paras. 32-34*).

Aids to station keeping

29. With a large number of ships and units who must keep accurate relative position the use of WS radar, particularly if fitted with P.P.I., is of great value; and as stated previously it may be desirable to use this set intermittently for station keeping before radar silence has been generally relaxed.

30. Radar Beacons types 951 or 952 (*Chapter XIV*) may be fitted in particularly important craft such as L.C.H. and L.C.N. so that other ships may easily distinguish them on P.P.I.

Aids to pilotage and beachfinding

31. Aids to pilotage include:—

*(a) The "Gee" system and receiver QH (*Chapter IX*).

*(b) The "Loran" system (*Chapter IX*);

and the following which may be used to mark swept channels or, possibly, laid ahead of the assault force to mark the approach to beaches:—

(c) Type 78T which is a portable directional radio beacon for use with type 291. It gives bearing but not range.

(d) Type 951 or 952 radar beacons which could be fitted in a boat or small craft. A security objection to the use of these beacons is that although they require to be triggered by a centimetric transmission, the response (on $1\frac{1}{2}$ metres) is all round and has a distinctive code.

(e) Type 255 which is a marker beacon for use with type 291. It suffers from the same security objections as types 951/952 but to a more marked degree.

(f) Metalised flags or reflectors on danbuoys.

(g) R.G. or directional visual means.

(h) P.P.I. display of the coastline.

Use of WS sets and P.P.I. for beachfinding. P.P.I. predictions

32. As fully explained in *Chapter IX*, P.P.I. display of the coast line may be most valuable for pilotage provided allowance is made for the effect of high and low land, and the width of the radar beam which tends to spread out the end of the land and to cast a "shadow area" along the coast. Correct interpretation of the P.P.I. must generally be a matter of experience but it is possible to produce accurate "predictions" of the coast as it should appear on P.P.I. from various distances, e.g., 10,000 yds. and 3,500 yds. off shore, for a given aerial height. A reproduction of one of the P.P.I. prediction chartlets actually used in operation "NEPTUNE" is shown in *Photograph 72*. The full white areas are those which should certainly paint on P.P.I. and the shaded areas those which will probably paint. E is the objective. A and D are points from which the operator can quickly report the range by using type 970 range strobe. In addition, track lines are shown 400 yds. apart so that the operator can readily gauge the amount the ship is off track to port or starboard. *Photograph 73* shows the actual P.P.I. picture later obtained from the same position.

33. These prediction chartlets were mounted in the radar office and by means of a "reflectorscope" were projected on to the face of the P.P.I. By adjusting the chartlet's position it was possible to fit it in with the actual P.P.I. detection and so check the ship's position with accuracy.

34. It must be emphasised that owing to the specialised skill required and considerable labour involved P.P.I. predictions cannot be provided generally. It is possible, however, to give some assistance and achieve fair accuracy by marking on the chart those features which should stand out on P.P.I. and which should prove reliable for ranging. *Fig. 65* shows part of a chart which was treated in this manner for operation "NEPTUNE." It should be remembered, however, that ranges of high coastline will only be accurate when viewed approximately at right angles, owing to the effect of beam width.

35. The above methods of assisting P.P.I. interpretation may be used by L.C.N.'s, L.C.T.(R)'s, or Bombarding ships. In the last two cases the WS set should previously be carefully calibrated using a corner reflector at the expected firing range.

* *Note.* These systems are dependent on the provision of large shore stations.

PROVISION AND CONTROL OF AIR COVER

Responsibility and provision of air cover

36. In the planning stage the responsibility for provision of air cover must be defined. This will generally devolve on the R.A.F. (*vide Chapter XV*), but shipborne radar will of course play an important part particularly in the early stages before shore radar and plotting arrangements have been established. Even then shipborne low air cover to seaward will be valuable.

Objects

37. The objects of air cover are to protect the anchorage and beaches by providing the necessary information for gunnery (usually barrage fire) and for fighter interception. When low flying air attacks are prevalent these two forms of defence are equally important and are often complementary; for example barrage fire may force aircraft to fly high where the fighters can get at them. Clearly it is advisable to vest the co-ordination of air warning radar in one authority who can control both forms of defence.

Difficulties

38. The particular difficulties in providing air cover and making full use of radar information during assault operations are:—

- (a) The large numbers of ships in the area which, together with decoy balloons, own radio transmissions and R.C.M., enemy R.C.M., etc., confuse the radar displays and make detection and individual tracking (particularly of low flying aircraft) very difficult within 10 or more miles.
- (b) Land echoes, which further confuse radar, especially WA sets.
- (c) The large numbers of aircraft, hostile and friendly, that come under detection. Generally these greatly exceed the number available for working up exercises, and at first ships' organisations and controlling officers may be somewhat overwhelmed.
- (d) The fact that enemy aircraft are prone to make use of land echoes by approaching from the direction where they are worst, or by approaching down a valley where they cannot be detected at all. Alternatively a low attack from seaward may be favoured.
- (e) The fact that more than one service is usually implicated in the provision and control of air cover, and may not at first be conversant with the others' capabilities and methods.

Method of achieving shipborne air cover

39. As regards the shipborne contribution to air cover, the following remarks apply and amplify *Chapters X and XIX*.

40. As in normal sea operations, complete cover can only be achieved by the use of several types of set, e.g., types 79, 281 and 277. Of these type 281 is very likely to be affected by land echoes, which may obscure the trace up to 20 miles off shore if the coast is very mountainous, and in such cases type 79 may be the only effective WA set.

41. When land echoes are bad, or in the presence of "window," it may be desirable to use one or more types 277 elevated to 4° or more to provide medium air cover.

42. In order to provide effective low cover it will be necessary to station special radar guardships with type 277 on the flanks, or even to station radar guardships well to seaward where they can give adequate warning and avoid the interference referred to in *para. 38 (a)*.

43. Also, owing to this interference and the effect of land echoes, WA sets are likely to be of little value at medium and close range unless—

- (a) short scale and short pulse length are used to improve discrimination;
- (b) the arc of sweep or responsibility is restricted to a sector;
- (c) targets are held while being tracked.

44. Given sufficient ships, therefore, a suitable organisation for as complete air cover as practicable would be:—

- (a) *Distant cover.* One type 79 and one type 281 using all round sweep on long scale, long pulse, and watching (but not holding) targets.
- (b) *Close cover*
 - (i) Three or four WA sets, preferably type 79, with sector responsibilities and probably using sector sweep on short scale short pulse and holding targets detected.
 - (ii) One or more additional WA sets on short scale short pulse and watching those sectors in which targets may be being held by (i).
 - (iii) One or more WS types 277 elevated as explained in *para. 41*.
- (c) *Low cover*
 - (i) Type 277 in ships on the flanks and/or to seaward.
 - (ii) Type 277T or similar set ashore.
- (d) *GA sets.* Type 285 sets, sweeping in sectors, may prove of value for supplementing the low and medium cover at close range.

45. In addition to the above :—

- (a) The *Controlling Ship's* radar should be left free of specific duties in order to investigate or interrogate doubtful targets, and watch the situation generally.
- (b) *Fighter Direction Ships (L.S.F.) or Tenders* should similarly be left free of guard duties, so that they can concentrate on interception.

46. Where P.P.I. is being used, extra watchkeepers will be required in ships in order to tell all plots under congested conditions.

47. *Y Information.* Y information of enemy aircraft is likely to prove of great value for warning, and should be related to the radar information.

Control of air cover. Reporting and plotting

48. Until a Sector Operations Room is established ashore, one ship must be detailed to control the air cover system and radar reporting. The ship may be the Force Commander's Flagship, one of the Fighter Directing Ships (L.S.F.) or Tenders, or some other ship specially fitted.

49. Whichever ship is selected, the following are necessary :—

- (a) An officer who has authority to control gunfire from ships and can exercise strategic control of fighters in the area (the actual interceptions will of course be carried out from the F.D. ships or tenders). The Controlling Officer should have the necessary G, F.D., radar, and R.A.F. officers on his staff.
- (b) Good communications, including a full Y organisation.
- (c) Facilities for handling information from the Movements Liaison System (*para. 10*).

50. **Reports** of radar detection are made by ships (or shore stations) direct to the controlling ship on radar reporting wave (usually W/T) using the Combined Air Warning Code (A.P. 3046). A separate R/T line should also be made available for short urgent reports, and for clearing up ambiguities or confirming identification of targets.

51. **Control** of the radar reporting wave under congested conditions will require an officer of considerable experience. With good control 6-8 tracks can be plotted simultaneously.

52. **Positions.** Owing to the interservice nature of an assault and the comparatively large distances between reporting ships and stations, geographical instead of relative positions are used when reporting. The Fighter Grid or Military Grid is normally employed in conjunction with the Combined Air Warning Code.

53. At the appropriate time a Sector Operations Room will be established ashore. The whole of the above organisation should then be incorporated in the S.O.R., to whom all radar reports will be made and from whom all warnings and calls for barrage fire should be issued.

Alternative method of organising and controlling radar for air cover, and reporting

54. An alternative method of organising and controlling radar for air cover, and reporting detections, is given in *Chapter XIX, para. 105, et seq.*

Minewatching

55. The necessity for tracking minelaying aircraft may well arise. The most satisfactory set for this purpose is probably type 293 using short pulse, and provided a lookout bearing has been given from a WA or other set it is possible under favourable conditions to detect the actual dropping of the mine.

56. Ships detailed for radar minewatching should of course be on the flanks. Ships in the centre of the anchorage are likely to have their radar blanked or confused by side echoes.

Putting on gunnery radar sets

57. In the absence of a Target Indicating set type 293, ships are likely to find difficulty in "putting on" gunnery radar sets if controlled fire is required. It will probably be necessary to hold the target with the WA set; alternatively the GA set should search and act as its own "putter-on" (provided the target can be identified as hostile).

SURFACE COVER

58. Except in a land-locked anchorage, surface radar cover will be required after arrival as a protection against enemy surface or U-boat attack. This cover will be provided by WS radar in ships on the flanks, and later by shore radar stations. Guardships with sector responsibilities will be desirable for reporting purposes.

59. Reports should be made to a controlling ship, usually the ship of the Force Commander, since he will be in the best position to check identification from his knowledge of the tactical situation and ships' movements and can give executive orders for dealing with a threatened attack.

60. The normal "Code for radar reports of surface contacts" (F.S.B. Article 148B) is used when reporting, but positions are taken from the Fighter, Military, or other grid system for the reasons given in *para. 52*.

61. When an S.O.R. (including a naval surface plot) is established the requirement for shipborne surface cover will probably lapse owing to the greater range obtained by shore radar if sited sufficiently high. A ship guardship to seaward may, however, still be considered a wise precaution to deal with very small objects such as "One-man" submarines operating within the radar shadow area of ships in the anchorage.

Controlled surface interception

62. Ships to seaward with an efficient WS set and P.P.I. display have been used successfully to control surface interceptions, e.g., by M.G.B.'s operating against E-boats outside the range of shore radar (see *Chapter XVI*).

63. Control signals from F.S.B. Article 148B may be used by W/T. Alternatively plain language R/T should be used.

64-69.

PERSONNEL

Officers

70. Qualified radar officers will be required on the planning staff, on the staff of the Force Commander, for the Air Controlling Organisation (*para. 49*), and later for any port maintenance organisation that may be established.

Ratings

71. Radar operators should be provided on the normal scale for ship radar sets. Additional maintenance personnel will however be required to look after the numerous special radio aids likely to be fitted in a combined operation. Special training in maintenance of these aids should be arranged.

Training

72. It is important that radar personnel should be provided in sufficient time to allow for training and working up. This applies particularly to the use of navigational aids, and to aircraft plotting teams. The working up time is always likely to be all too short, so that it is essential that a good proportion of personnel should have had previous experience.

MAINTENANCE

73. Before the operation is launched the maintenance and tuning of radio equipment in the many small craft concerned is most conveniently carried out by having a number of self-contained mobile maintenance units, rather than by attempting to establish an even larger number of static organisations.

74. After a foothold has been obtained it may be desirable to establish one or more port radar organisations. This will however depend on circumstances, *i.e.*, the distance from the advanced base and whether a maintenance ship has accompanied the expedition.

CHAPTER XVIII

RADAR IN AIRCRAFT

1. Cruisers were once the "eyes of the fleet" but when flying is possible aircraft have to a large extent taken over this function. Radar can give aircraft a valuable increase in the extent of their vision, even by day, and enables them to carry out forms of attack which would otherwise be impracticable.

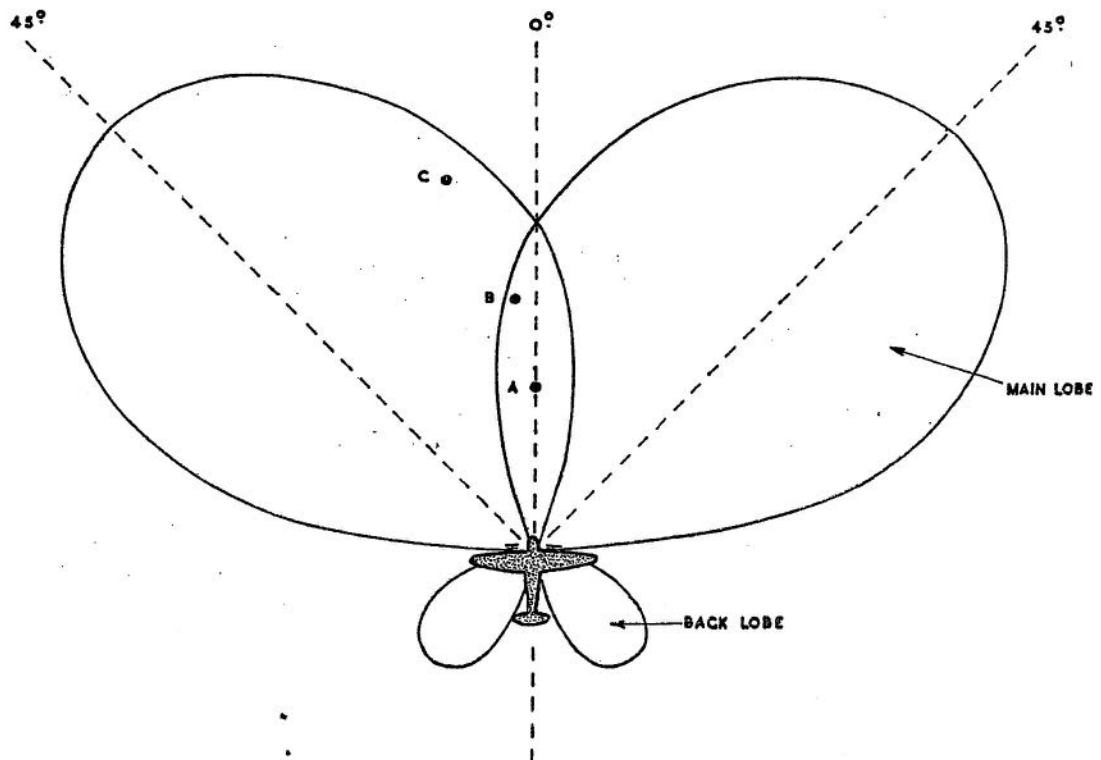
EQUIPMENT AND CAPABILITIES OF A.S.V.

Types of Search radar (A.S.V.) fitted in aircraft

2. Search radar fitted in aircraft is known as A.S.V. (Air-Surface Vessel). The older types (A.S.V. Mk. IIN and ASB) are ahead looking only. Newer types are all round looking (A.S.V. Mk. XI) or cover a wide sector ahead (ASH).

3. **A.S.V. Mk. IIN** is fitted in some T.B.R. aircraft (Swordfish and Barracuda) and in A.B.R. aircraft (Walrus). It operates on $1\frac{1}{2}$ metres.

4. Two aerial arrays are fitted, mounted on opposite wings and set out at an angle, giving a horizontal coverage diagram of the shape shown in *Fig. 66*. It will be seen that the best ranges are obtained on the bows, at a relative bearing of about 45° , while detection right ahead is not so good. The object of this arrangement is to give the best compromise between ahead detection and maximum breadth of sweep when on search. Detection abaft the beam is not practicable.



*Fig. 66—Horizontal coverage diagram for A.S.V. Mark IIN, illustrating the directions of best detection which are at about 45 degrees on each bow. The appearance on "A" display of targets A, B and C is shown in *Fig. 67*.*

5. The aerials are energised alternately, so that for targets ahead two echoes are received (on the same principle as in beam switching with ship gunnery radar sets). The echoes are shown on an "A" display which is similar to that used in ships, except that the trace is vertical and the twin echoes are shown one on either side of the trace as in *Fig. 67*.

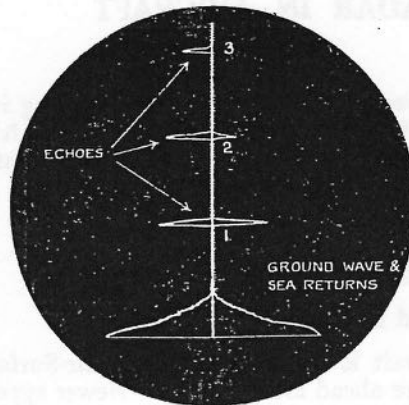


Fig. 67—Type of "A" display used with A.S.V. Mark II, showing ground wave and sea returns, and echoes, 1—right ahead, 2 and 3—to port.

6. When the target is right ahead, two equal echoes will appear, one either side of the trace. When the target is to port or starboard the echoes will be unequal, or one echo only may appear to port or starboard, as shown in *Fig. 67*. Range is read off vertically.

7. The vertical coverage ahead is nearly complete, as shown in *Fig. 68*.

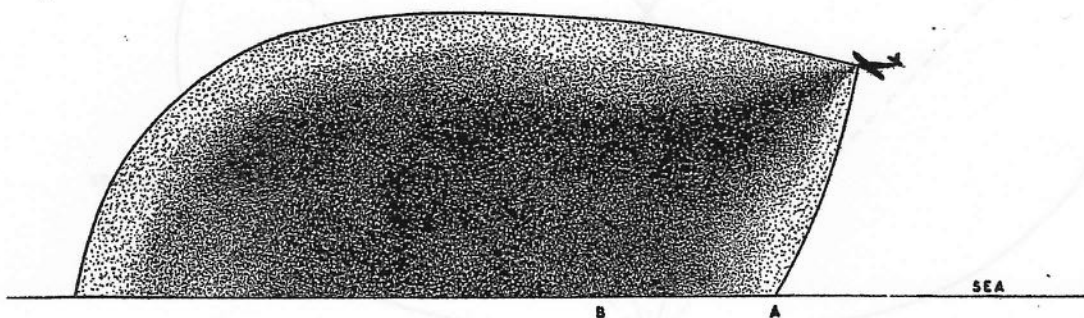


Fig. 68—Vertical Coverage of A.S.V. Mark IIN, omitting back radiation. The sea returns will be strong from point A, but weaker at greater range (e.g. from B) since the transmission strikes the sea more obliquely.

8. ASB is fitted in Avenger type T.B.R. aircraft. It operates on about 60 centimetres. The layout and results are very similar to A.S.V. Mk. IIN, but the aerials can be rotated so as to give the best results in any desired direction between the beam and the bow. The beam position gives the greatest width of search and the ahead position the best "homing."

9. **A.S.V. Mk. XI** is fitted in those T.B.R. aircraft (some Swordfish and Barracudas) who can take this heavier form of equipment. It operates on 3 cms. and uses a spinning type of aerial and reflector, mounted beneath the fuselage, which gives all round cover. Display is on P.P.I. The aerial also scans in vertical steps, giving an effective vertical coverage diagram as shown in *Fig. 69*.

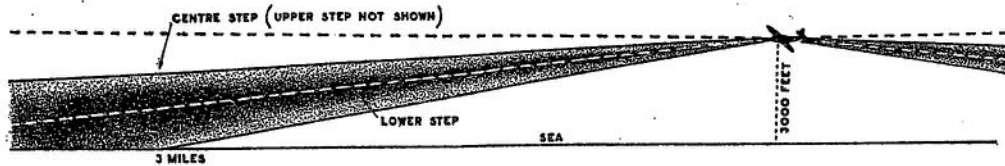


Fig. 69—Vertical coverage of all-round looking centimetric A.S.V. (Mark XI) in a Barracuda. The spinning aerial scans in three steps, the centre of the steps being 0 degrees, $2\frac{1}{2}$ degrees and 6 degrees below the horizontal axis, and the effective width of each step being 7 degrees. For clarity the upper step has been omitted in the figure, but this step may become the most important when the aircraft is diving.

10. Apart from all-round cover and P.P.I. display, the advantages of this equipment over earlier types include:—

- (a) Better discrimination, which enables specific targets to be selected out of vessels in formation.
- (b) Better range performance, particularly at low heights against small targets.

11. **ASH** is a lighter type of centimetric A.S.V. which may be fitted instead of A.S.V. Mk. XI. It covers an arc 75° on either bow and gives continuous presentation. ASH may also be used for Air Interception, *vide para. 51*.

Range performance of A.S.V.

12. The maximum range obtained by A.S.V. depends upon a number of factors, chief of which are the height of the aircraft, the size and inclination of the target, the state of the sea, efficiency of operating, and good maintenance of the equipment. The following typical results are based upon average conditions and a target inclination of 45° (or 135°).

TYPE OF TARGET	HEIGHT OF AIRCRAFT (feet)	DETECTION RANGE (miles)	
		A.S.V. MK. II N ASB (on best bearing)	A.S.V. MK. XI
<i>Battleship</i>	5,000	35*	40
	2,000	27*	35
	1,000	20*	33
<i>Large Cruiser</i>	5,000	25*	33
	2,000	20*	30
	1,000	17*	25
<i>Destroyer</i>	5,000	17	27
	2,000	12	22
	1,000	9	20
<i>Fully Surfaced Submarine</i>	5,000	10	16
	2,000	7	12
	1,000	5	11

* 5 miles less with ASB.

LIMITATIONS OF A.S.V.

Liability to interception and D/F and its effect on the use of A.S.V.

13. The possible range of enemy interception of A.S.V. increases with the aircraft height, and may considerably exceed the figures given in *Chapter V, paras. 63–64*. Such is the value of A.S.V. to aircraft, however, that it will be exceptional to impose A.S.V. silence except:—

- (a) In the case of earlier marks of A.S.V. in good visibility by day when it has little advantage and is not normally used. (Centimetric A.S.V. is normally used in all visibilities.)
- (b) During the approach in a surprise attack, *e.g.*, on the enemy coast.

14. Alternatively, it is possible to use methods of deception which enable A.S.V. to be used with less chance of losing surprise. One of these methods called "**Vixen**" which is used against U-boats consists in reducing the radar output power as the target is approached in such a way that the enemy receives a decreasing or constant strength of signal in his receiver, instead of an increasing signal, and so imagines that the aircraft is going away or remaining at a distance.

Sea Returns

15. Sea returns correspond to "wave-clutter" in shipborne sets, but their effect is usually more pronounced. It will be seen from *Fig. 68* that the transmission strikes the sea at A nearly at right angles and much of the energy will be received back and will obscure the first part of the trace as shown in *Fig. 67*. At the point B in *Fig. 68*, the transmission strikes the sea more obliquely, and consequently the sea returns at that range are weaker.

16. With earlier marks of A.S.V., the sea returns extend to about 6 times the aircraft's height, but in very rough seas may extend much further. For example, an aircraft flying at 6,000 ft. in rough weather might experience sea returns up to the first 6 or 8 miles of the trace.

17. With new (centimetric) A.S.V., sea returns increase up to heights of about 3,000 ft. after which they begin to fade in intensity; and the effect of rough weather is not so pronounced.

18. In rough weather, sea returns may make it difficult or impossible to locate very small targets at close range, and to follow targets right in (*e.g.*, during the course of an attack). A filter (*cf.* "anti-clutter device" in ship sets) may be fitted to mitigate this effect. In calm weather, there is normally little difficulty in following targets right in provided the aircraft is at a low altitude.

Need to Switch off earlier marks of A.S.V. periodically

19. It is necessary to switch off A.S.V. Mk. IIN and ASB periodically (usually for 5 minutes every 15), to rest the equipment and the operator, and to provide a W/T listening period if reception is doubtful due to A.S.V. interference. These breaks reduce the overall efficiency of search, especially against small targets.

Snowstorms and thunderstorms

20. These cause interference and may seriously reduce the efficiency of A.S.V.; they may also obscure targets beyond them.

Fatigue

21. Normally there is only one operator available, so that tricks cannot be worked as in ships. As a result the efficiency of search by A.S.V. usually begins to deteriorate after an hour, and after two hours may deteriorate rapidly.

I.F.F., INTERROGATORS, AND RADAR BEACONS

22. I.F.F. Mark III is fitted in T.B.R. and A.B.R. aircraft, and I.F.F. Mark IIIG in fighters, as fully explained in *Chapter XIV*. The only additional point to mention here is that I.F.F. in a shadowing aircraft is often used as a radar beacon (or "Rooster") to enable an air striking force to home on the target.

23. A.S.V. Mk. IIN triggers I.F.F. direct and is therefore its own interrogator. Other types of A.S.V. are fitted with a separate interrogator called "Lucero."

24. Radar beacons (usually type 251M) are used in conjunction with A.S.V. Mk. IIN or Lucero to enable aircraft to home on to friendly ships or shore stations, as explained in *Chapter XIV*.

TACTICAL USE OF A.S.V.

25. The authorities on the tactical use of A.S.V. are C.B.04040 "Naval Air Fighting Instructions" and "Naval Air Tactical Notes" issued to ships carrying aircraft. For full and up-to-date information reference should be made to these publications. The following notes are only a general guide to the subject.

26. The main tactical uses of A.S.V. are for :—

- (a) Search.
- (b) Shadowing.
- (c) Attacking, with or without illuminants.
- (d) Co-operation with Submarine (usually by long range R.A.F. reconnaissance aircraft).
- (e) Navigation and minelaying.

SEARCH

27. The value of A.S.V. for aircraft search is that it enables aircraft to spread to a greater distance apart and so cover a larger area (or search a given area more quickly); and the efficiency of search is very much less dependent on visibility.

28. As an example, aircraft fitted with A.S.V. Mk. XI flying at 3,000 ft. searching on a parallel track for a single cruiser would be spaced 40 miles apart. This allows a large margin for overlap and under good conditions could be increased to 50 miles.

29. The overlap referred to is necessary for two reasons:—

- (a) Possible relative navigational errors of adjacent aircraft.
- (b) The necessity for investigating contacts.

30. On account of (a) above, it is usual for aircraft to proceed to investigate contacts obtained at rather more than half the distance between them. In the case quoted in *para. 28*, the investigating distance might be 30 miles, as illustrated in *Fig. 70*. Thus, it may occur that two aircraft investigate the same contact, but this is better than risking failure to investigate at all.

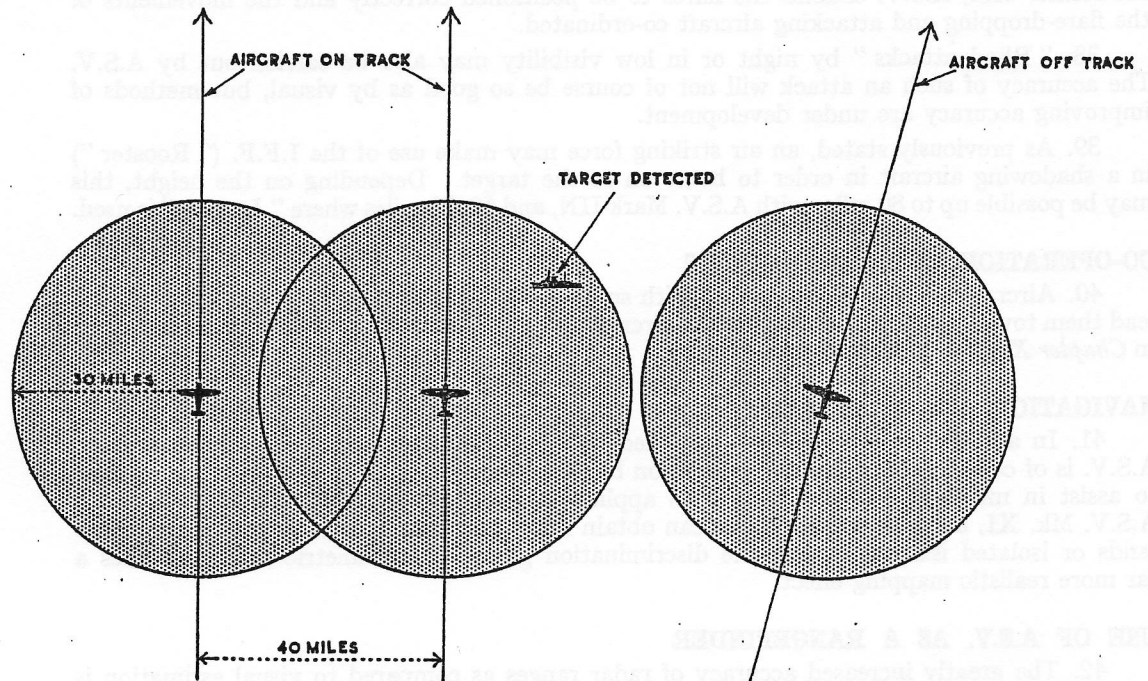


Fig. 70—Showing three aircraft with A.S.V. Mark XI on a parallel back search for an enemy cruiser (detection range thirty miles). The area covered at any one moment is shown shaded. Overlap (in this case ten miles) allows for aircraft getting off track or proceeding to investigate a contact.

31. It is the normal practice to investigate and visually identify contacts both by day and night (unless of course they are giving I.F.F. response), and it is not normally the practice to make an enemy report on A.S.V. contact alone. The necessity for investigation is of course likely to leave a temporary gap in the search, and after investigation of a contact whose credentials have proved satisfactory the aircraft has to return to the proper track and possibly carry out a short search astern in order to close the gap.

Operational Height at which aircraft search

32. Since the detection range increases with height, it might be supposed that Searching aircraft would fly as high as possible but this is not so for the following reasons:—

- (a) Aircraft flying high are more easily detected by enemy shipborne or shore radar and are therefore more vulnerable to attack and less likely to achieve surprise.
- (b) Within limits, the sea returns increase with height, and in rough weather may obscure very small targets (e.g., U-boats trimmed down) which it is desired to detect.
- (c) It is undesirable to fly for long periods through cloud.
- (d) The height at which search is carried out must be related to the action to be taken on obtaining contact.

33. For these reasons, a compromise is necessary, and search aircraft usually fly at about 1,000–1,500 ft. Where maximum detection range is of paramount importance and outweighs considerations of security, the height may be increased to 3–4,000 ft. or more. In the case of A/S search on the other hand the usual height is 500–1,000 ft. in order to enable the aircraft to develop an attack as soon as possible after contact.

34. When contact is obtained, it is in any case usual for the aircraft to lose height (while still maintaining A.S.V. Contact), in order to reduce as far as possible the likelihood of detection by enemy radar.

SHADOWING

35. A.S.V. enables shadowing aircraft to maintain contact while confusing the enemy as much as possible by using cloud cover, changing height, and retiring and approaching from different bearings. A.S.V. reduces the risk of enemy evasion by splitting his forces.

ATTACK

36. Perhaps the biggest advantage that A.S.V. confers on attacking aircraft is the ability to make use of cloud cover. In the case of strikes, the forces can be split up, correctly stationed and can thus deliver a co-ordinated attack from different directions. Without A.S.V. such an attack is out of the question in poor visibility or cloudy conditions.

37. Night attacks may be carried out with or without prior illumination by flares. In the former case, A.S.V. enables the flares to be positioned correctly and the movements of the flare-dropping and attacking aircraft co-ordinated.

38. "Blind attacks" by night or in low visibility may also be carried out by A.S.V. The accuracy of such an attack will not of course be so good as by visual, but methods of improving accuracy are under development.

39. As previously stated, an air striking force may make use of the I.F.F. ("Rooster") in a shadowing aircraft in order to home on to the target. Depending on the height, this may be possible up to 80 miles with A.S.V. Mark IIN, and 60-70 miles where "Lucero" is used.

CO-OPERATION WITH SUBMARINES

40. Aircraft are able to co-operate with submarines fitted with I.F.F. type 253MW, and lead them towards a target located by the aircraft A.S.V. The method of doing so is described in *Chapter XIV* and illustrated in *Fig. 62*.

NAVIGATION AND MINELAYING

41. In addition to the facilities provided by shore radar beacons in friendly territory, A.S.V. is of considerable value for navigation by detection of land, and can therefore be used to assist in minelaying operations. This applies particularly where P.P.I. is fitted, as in A.S.V. Mk. XI, but even earlier types can obtain fairly accurate fixes from prominent headlands or isolated islands, though the discrimination given by centimetric radar provides a far more realistic mapping effect.

USE OF A.S.V. AS A RANGEFINDER

42. The greatly increased accuracy of radar ranges as compared to visual estimation is made use of in enemy reporting, and in the final stages of attacking. A.S.V. Mk. XI has an expanded trace which can be used for accurate ranging of the last 6 miles of the approach.

43-49.

A.S.V. IN R.A.F. AIRCRAFT

50. R.A.F. long range reconnaissance aircraft are fitted with A.S.V. normally operating on 10 cms. The remarks above apply generally.

RADAR IN NIGHT FIGHTERS

51. Fighters used for low visibility and night interception may be fitted with a form of radar for **Air Interception (A.I.)**. The present intention for naval fighters (Hellcat or Firefly) is to fit a modified form of ASH which scans in the vertical plane from 30° below the horizontal to 10° above, at the same time carrying out its 150° sweep ahead. This set should give a range of about 4 miles on an enemy bomber within the detection zone. These figures determine the accuracy for location and height within which the fighter directing radar (*Chapter XI*) must position the fighter.

PART III

EMPLOYMENT, ORGANISATION AND CONTROL OF RADAR

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CHAPTER XIX

EMPLOYMENT, ORGANISATION AND CONTROL OF RADAR AT SEA

EMPLOYMENT OF RADAR

1. The best results from radar are of course achieved when its unrestricted use is permitted.

The question of restricting the employment of radar at sea arises because any radio transmission is capable of disclosing the presence of the transmitting ship. As with W/T therefore officers must use judgment and learn when radar should be used, when radar silence should be kept, and when it should be relaxed or broken.

2. In making the decision, the questions to be answered are :—

- (a) What is the extent of the danger in using radar ?
- (b) What will be gained if radar is used, and what will be lost if it is not used ?
- (c) What is the alternative to using radar ?

3. In the past there has in general been a tendency to attach too much importance to the security aspect. Radar is more difficult to intercept and D/F than W/T, neither does radar usually travel so far. At the same time its value is considerable and will further increase as most organisations become very largely dependent upon it. It should be remembered that, so far as is known, no ship has yet been sunk through using radar ; but several have been sunk or damaged through failure to use it, or failure to switch on in good time.

4. It is not possible to lay down hard and fast rules when to employ and when not to employ radar. This must always be a matter of judgment and will depend upon the conditions at the time. For this reason the normal practice in different Fleets has differed, e.g., the Mediterranean Fleet operating in fine weather and waters covered by enemy air reconnaissance have tended to use aircraft warning radar more than the Home Fleet.

5. The following remarks are therefore only a guide. Where the remarks are framed as instructions they are of course subject to their acceptance, amplification, or modification by Commanders-in-Chief in Fleet or Station orders.

Extent of risk in using radar

6. The risk of using radar depends upon :—

- (a) The possible range of interception, and the practicability of D/F.
- (b) The extent and skill of the enemy's interception and D/F, i.e., his " Y " organisation.

7. **Interception.** The probable and possible interception ranges for all sets are given in *Chapter V, paras. 63 to 65*. It will be seen that alternative figures are given according to whether the enemy has " average " or highly developed listening apparatus, and also for conditions of anomalous propagation. As a matter of practical politics it is recommended that the smallest figure (*Column 1 of para. 63*) should always be taken until there is evidence that it has been exceeded, or unless special security is required.

8. **D/F.** As explained in *Chapter V, para. 69*, D/F is a comparatively simple matter from shore stations, but is not nearly so easy from ships.

9. **The combined interception and D/F risk** is summed up as follows :—

- (a) Interception is not easy, and bearings if taken are likely to be inaccurate especially from ships.
- (b) Sets with short wavelengths and narrow beams are the safest.
- (c) The newest wavelengths are safest.
- (d) Sweeping makes the enemy's task harder.
- (e) Restriction of the number of sets of one type in use at the same time may give a slight increase in security.

10. **Enemy " Y " organisation.** The above remarks and those in *Chapter V* assume that the enemy is in fact listening to our transmissions. This may well not be the case, particularly with ships at sea, and for this reason alone the danger should not be exaggerated.

11. On the other hand it would be quite possible for an enemy to concentrate his efforts on efficient interception, and an enemy with inferior radar might well do so in order to restore the tactical balance as explained in *Chapter XV*. Intelligence on the latest known state of the enemy's " Y " organisation afloat and ashore is promulgated whenever obtained. The enemy's " Y " organisation ashore is always likely to be more comprehensive and efficient than that afloat.

Danger and disadvantages of not using radar

12. The following disadvantages and possible dangers should be borne in mind if radar is not used :—

- (a) Lack of warning outside visual range. The armament will require to be kept at a higher state of readiness, as will also fighters.
- (b) There is no guarantee that the enemy will not use his radar, and if he does so he will be at a considerable tactical advantage whether the object is attack or evasion.
- (c) The efficiency of most organisations, and particularly gunnery and fighter direction, will suffer considerably unless radar is switched on in sufficient time.

13. It should be remembered that radar and its associated organisation (e.g., plotting) take a little time to settle down and give results, and will not immediately spring into full efficiency after a long period of radar silence.

Other factors affecting the use of radar

14. In addition to the probable advantages and disadvantages given above, the following factors should be considered when making the decision whether or not to use radar :—

- (a) The object of the operation.
- (b) The likelihood of enemy ships or aircraft being in the vicinity, and whether of any special type, e.g., raiders or U-boats.
- (c) The proximity to enemy bases and to possible enemy listening stations.
- (d) Whether the enemy is or may already be aware of the unit's position, through air reconnaissance, breaking of W/T silence, or other reasons. For example there is less object in keeping radar silence if long range communication is being, or has recently been, carried out.
- (e) Whether the operation is a routine one, and therefore likely to be known to the enemy.
- (f) Whether the unit is a particularly tempting target.
- (g) The visibility and weather which may affect the operation of aircraft or small ships.
- (h) The proximity of other friendly units who may be keeping radar silence.
- (j) The dependance that can be placed on own "Y" organisation to disclose the presence of shadowing aircraft or other enemy units.
- (k) The need for relaxation of a proportion of the ships' company.
- (l) The need for periodical rest and maintenance of equipment, and rest for operators.

15. All these points and perhaps others, will affect the decision, though they may affect it in different ways under different circumstances. For example, while attack normally calls for the full use of radar, a surprise attack on enemy coast may require special security measures. Again, evasion may suggest radar silence but in the vicinity of superior enemy forces, radar may be the only method of avoiding being surprised or ensuring evasion.

RADAR POLICY

16. After considering the factors mentioned above, it is the duty of the Senior Officer to decide upon and promulgate a "**Radar Policy.**" This is done by means of the signal for "*Assume Normal radar policy, or policy indicated :—*"

1. *Silence.*
2. *Silence except for radar guardships.*
3. *No restrictions.*
4. *As laid down in orders for the operation."*

If it is desired to impose or relax restrictions on certain sets but not on others, this must be signalled separately.

17. Ships will then conform to the policy ordered, but it must be remembered that the situation may change rapidly and before the Senior Officer can promulgate a revised policy. Ships must therefore use their initiative and, if necessary, anticipate the Senior Officer's instructions.

18. It is a universal rule that **ALL RESTRICTIONS ON RADAR ARE AUTOMATICALLY REMOVED WHEN IN THE PRESENCE OF THE ENEMY (SHIPS OR AIRCRAFT) OR WHEN ACTION IS IMMINENT.** Gunnery sets must be switched on in sufficient time to give a good plot.

19. Detached ships must decide on their own radar policy, but should bear in mind the possible effect of their radar transmissions on nearby units who may be keeping radar silence.

A guide to the policy for using different radar sets

20. The following is a *guide* to the policy for using different radar sets, based on the normal practice at present.

21. **WA Sets**, which have the longest interception ranges, should not normally be used when outside range of enemy aircraft. When within range the use of one or more WA sets will normally be expedient, and when enemy aircraft are known to be in the vicinity all available WA sets should be employed.

22. There is little danger of interception of WA sets by shore stations when more than 200 miles from enemy territory.

23. Fighter Direction is impracticable without the use of WA sets (and R/T).

24. **WS Sets**, when employed for *surface warning*, should normally be used for detection of enemy ships, rendezvous with friendly units, or station-keeping when the visibility is less than horizon distance (since modern sets achieve this range against large ships).

25. When the function of WS sets is primarily to detect U-boats, WS sets are normally used when the visibility is less than 5-6 miles. It should be noted that in A/S warfare interception of a WS set is most likely to cause a U-boat to dive. The use of WS sets is therefore very unlikely to endanger a convoy.

26. On other occasions, the use of WS sets is unnecessary as far as surface warning is concerned.

27. If restrictions are imposed on the use of WS sets, which is unusual, consideration should be given to permitting intermittent use for station keeping in low visibility.

28. Modern WS sets give the best *low flying aircraft warning*. Consequently, when low flying attack is possible, it will be desirable to keep at least one such set in use, irrespective of the visibility and surface warning requirements.

29. **10-cm. WC Sets**, when used for *surface warning*, should follow the policy for WS sets. When used for *target indication*, they should be switched on automatically in time to carry out their function, *e.g.*, when approaching hostile or unidentified aircraft are within 20–25 miles.

30. **1½ metre WC Sets** lie within the waveband of German U-boat search receivers. Consequently, in areas where U-boats may be present, their use is generally only permitted in the following circumstances :—

- (a) *For Surface warning*, if no WS or centimetric WC sets are available in the unit. Intermittent use for station keeping may however be permitted in bad visibility. Restrictions are removed when U-boats are known to be attacking.
- (b) *For Aircraft warning*, if no WA set is available. There is, of course, no restriction when enemy aircraft are known to be in the vicinity.

31. **Gunnery Sets** need not be switched on continuously but may be used as required for exercise and should be tested once a watch, unless orders are given to the contrary. In the case of 50-cm. sets the transmission should be away from the enemy coast or supposed direction of enemy units.

32. **Interrogators** use 1½ metres and therefore suffer from the same danger as 1½ metre WC sets though the possible interception range is appreciably less. Transmission, which is normally directional, lasts 10 seconds only on each occasion of interrogating. Provided this is not exceeded, restrictions are not usually imposed since :—

- (a) The radar recognition system is an integral part of the radar warning system.
- (b) The alternative methods of effecting recognition (starshell, searchlight, or visual recognition signals), are usually a great deal more dangerous than using the Interrogator.

33. When required for continuous tracking of low or distant aircrafts' I.F.F. responses, Interrogators should follow the policy for 1½ metre WC sets.

34. **I.F.F.** There are normally no restrictions on the use of I.F.F. in ships. The occasions on which it should be switched on are given in *Chapter XIV, para. 52*.

35. **Radar Beacons** used for homing aircraft should normally be used when so required, as explained in *Chapter XIV, para. 132*. When special security is required the use of I.F.F. instead of the Radar Beacon may be ordered for homing, *vide Chapter XIV, para. 122*.

36. **A.S.V. in Aircraft** (*see Chapter XVI*). The policy for employment of A.S.V. in aircraft is usually ordered by the Senior Officer, Aircraft Carriers, but it should be reported to the Senior Officer since it affects the security of the Fleet, and he might wish to modify it. Normally, earlier types of A.S.V. (Mk. IIN and ASB) are not used in good visibility, but are used on other occasions, while centimetric A.S.V. sets (Mk. XI and ASH) are used at all times.

37. It is recommended that, in order to simplify signalling, the **normal policy** to be followed should be laid down in Fleet or Station orders. The normal policy will of course require revision from time to time in the light of fresh intelligence concerning enemy "Y" activities.

38–44.

ORGANISATION AND CONTROL OF RADAR FOR AIR COVER

(Note :—The organisation described in *paras. 45–102* is that which has been developed in the period 1939–1944. With the development of continuous aerial rotation and plan radar display, and also VH/F R/T, it is likely that the present methods will be considerably modified, as briefly described in *paras. 105–110*.)

45. The objects of radar for aircraft warning are given in *Chapter X, para. 1*. The provision of reliable air cover requires careful organisation and control; unless attention is paid to these matters, there is a risk of surprise attack from an unwatched direction or height.

46. The following remarks apply to a large unit where sufficient radar sets of the right type are available, and where there are no restrictions on the use of radar. In a small unit, or where radar restrictions are in force, the organisation will be less extensive and the reliability of air cover will be proportionately less.

Provision of air cover and methods of sweep, etc. (*see also Chapter X*)

47. As explained in *Chapter X*, complete air cover for all heights can only be obtained by the use of several sets, *e.g.* :—

High and medium aircraft	...	...	...	WA Types 79 and 281
Low aircraft	...	...	...	WS Type 277

At least one of each of these or similar types should therefore be employed when available.

48. **Type of sweep.** It is also necessary to cover the area efficiently in azimuth. *All round sweeping* is employed in the absence of other orders since :—

- (a) It allows for breakdown or reduced efficiency of other ships' radar.
- (b) With normal air density, the rate of sweep of WA and WS sets is sufficient to cover all sectors efficiently.
- (c) It avoids the necessity of reallocating sectors if a ship parts company or her radar breaks down.

49. *Sector Responsibilities* for all ships or for selected ships may, however, be preferable under the following circumstances :—

- (a) If the air density is considerable, then control is likely to become very difficult, as is also the telling and reporting of raids. Ships detailed for sector responsibilities will become responsible for *reporting* raids in their allotted sectors. There is however no objection to continuing all round sweep, and this will be most convenient if P.P.I. is fitted.
- (b) If special attention is required to be paid to a particular sector, *e.g.*, to guard against low flying aircraft, or because of bad land echoes in that direction. Ships so detailed must use their judgment whether to use continuous sweep and P.P.I. display, or whether to use hand training and "A" display; the decision will depend on the size of the sector allotted and whether it can be covered and raids told efficiently by the latter method.

50. Whether all round or sector sweeping, or both, are employed it is necessary to ensure that if one ship holds a target, or watches a number of targets, the remaining sectors are efficiently covered. This is a matter for good control (*vide para. 102*) coupled with intelligent team work on the part of ships keeping watch.

51. The normal rates of sweep of sets used for aircraft warning are given in *Chapter X*.

52. **Range scales.** Normally ships will use the longest range scale when keeping watch against aircraft. In certain circumstances, *e.g.*, in the case of type 281 near land, better results are achieved by using the shorter range scale and one or more ships may be detailed to do so; this will probably be combined with the allocation of a sector responsibility. One or more other WA sets must of course remain on long scale in order to provide long range cover.

53. When the shorter range scale is used, short pulse length should also be used to improve discrimination.

54. **Small ships** are fitted with low power sets such as WC type 291. This set can give useful warning but does not provide complete or long range cover. It is usual therefore to use all round sweep, and unless responsibility is definitely allocated the set is used primarily as a warning and target indicating device for the ship herself, rather than for the unit.

Controlling ship

55. In order to organise and maintain reliable cover, as explained in the preceding paragraphs, a **controlling ship** is necessary. This requirement is distinct from that for the radar guardships (*para. 65*) who actually provide the radar information, although the control ship may also be one of the guardships.

56. The controlling ship is normally specified in standing orders and is usually either the Senior Officer or the Senior Officer Aircraft Carriers. On one hand, an aircraft carrier often has more experience of controlling and may also be in the best position to know the movements of friendly aircraft; on the other hand, there is some advantage to be gained by leaving carriers free of other duties so that they can concentrate on fighter interception.

57. The *duties* of the air cover controlling ship are :—

- (a) Subject to the radar policy issued by the Senior Officer, to detail the necessary radar guardships and standby guardships and control the operation of their radar, and also that of other ships keeping watch on appropriate sets, so as to maintain reliable air cover for the unit.
- (b) To order, by means of the Guard Duties Signal (*F.S.B. Article 210*), the types of detections to be reported and the methods of reporting them, if this is not already laid down.
- (c) To maintain a complete and up-to-date picture of the air situation. This involves co-ordinating all available "Y" information and other intelligence with the radar information.
- (d) To ensure that aircraft carriers or other ships carrying out fighter direction have sufficient radar information to make interceptions.
- (e) To control the radar reporting wave, or other wave/s so far as their use for radar reporting is concerned.
- (f) Subject to local orders, to issue air raid warnings and notices to the fleet.
- (g) To inform the fleet when approaching friendly aircraft are about to come into sight.
- (h) After air attack, to inform the fleet when the area is clear of unidentified echoes.

58. Under certain circumstances, the Controlling Ship may also be given the responsibility of controlling the fleet's A.A. gunfire, since she is in a good position to co-ordinate defence by gunfire and fighters.

59. In the controlling ship, control is exercised from the Main Aircraft Display Plot. Some remarks on controlling technique are given in *para. 100 et seq.*

60-64.

Radar guardships

65. Radar guardships are detailed so as to maintain reliable air cover for distance and height as explained in *para. 47*. Subject to radar considerations, and the necessity for each ship having a periodical rest for maintenance, it is advisable to detail guardships who are in the best positions for easy communication. This applies particularly at night if V/S is used for reporting.

66. On the other hand, if low-flying attack is expected from a particular sector it may be desirable to detail a low cover guard in this direction at some distance from the main body. The advantage of this cover must, however, be weighed against the disadvantage of spreading out the fleet and thus increasing its chance of discovery; and the extended guardship will be outside close support.

67. Radar guardships should inform the controlling ship when they have assumed duty and they are then responsible for reporting detections in accordance with the guard duties signal. In the absence of a guard duties signal, all detections should be reported except friendly aircraft out of sight. (The possibility of enemy aircraft simulating I.F.F. must, however, be borne in mind, and when in doubt "friendlies" should also be reported, particularly if a large number are approaching the Fleet.)

68. Unless specifically ordered to hold a target, guardships must be careful to maintain a search over their whole sector, and must avoid concentrating on a portion of it to the detriment of reliable cover.

69. If there is congestion radar guardships must use their judgment as regards priority of reporting targets, but generally priority should be given to first detections, unidentified groups closing the fleet, and raids which our fighters are known to be intercepting. It can be assumed that the fighter directing ship is tracking own fighters.

70-71.

Stand-by radar guardships

72. Stand-by radar guardships may be detailed to back up the guardships, and to ensure that a sufficient number of ships are keeping watch in case air density suddenly increases, observing that there might otherwise be no ships (other than the guardships) with aircraft warning sets switched on.

73. Stand-by guardships are therefore the "long-stops," and should keep a general watch all round, or in the sector ordered. If the guardships are heard to signal misleading or incorrect information, or should they fail to report vital information or other detections within a reasonable time, a stand-by guardship should report accordingly.

74. Stand-by guardships may also be controlled :—

(a) To watch a temporarily uncovered sector if the guardships are concentrating on another sector.

(b) To report heights of raids and thus avoid slowing up the effective sweep of guardships.

Other ships

75. Ships not detailed as radar guardships or stand-by guardships should take the opportunity of carrying out routine tests and any necessary maintenance work. They are, therefore, not obliged to keep aircraft warning watch, but sets should be at a quarter of an hour's notice unless permission for a longer period has been obtained.

76. Except when carrying out such tests, etc., or if the radar policy allows only guardships to transmit, other ships will, as a rule, keep aircraft warning watch. They should then act in the same manner as stand-by guardships, *i.e.* back up the guardships by watching sectors in which raids are not being reported; but they should not make reports until the guardships or stand-by guardships have had a reasonable opportunity of doing so, or unless the information is considered vital.

If no radar guardships are detailed

77. If no radar guardships are detailed, and the radar policy allows, all ships with suitable aircraft warning radar should keep all-round watch and assume the responsibility of guardships. In these circumstances, permission must be obtained *before* closing down for tests, etc.

Manning of aircraft direction rooms

78. Ships keeping aircraft warning watch must also keep their aircraft direction rooms manned in order to follow the air situation generally and avoid duplicating reports. The controlling ship and guardships must of course man aircraft direction rooms more fully than other ships.

Codes used for reporting

79. The standard code for making reports is contained in *F.S.B. Article 148A (Radar reports of Aircraft)*. The code consists of :—

- (a) Groups for reporting relative bearing and distance of raids.
- (b) Amplifying signals concerning height, movement, etc.
- (c) Control Signals.

80. A *Raid letter* for identification purposes should be allocated in advance to each ship. These raid letters precede all reports made in code and in addition to distinguishing the various plotted tracks, make the continuous use of call-signs unnecessary.

81. If a raid under report splits into separate units the raid letter is retained and the units are numbered, e.g. C1 and C2.

82. *Positions* of reporting ships are not normally signalled, but should be added if the ship is a considerable distance from the main body or from other units who may intercept the report, i.e. whenever the reporting ship's position may be in doubt. Geographical positions or lettered screening diagram positions may be used. If the reporting ship is more than a few miles away, the controlling ship and intercepting ships must remember to make the necessary allowance when plotting.

83. The *Combined Air Warning Code* (A.P. 3046) may be used instead of the naval system when :—

- (a) Air cover is being provided by more than one service, or the reports from one service are of value to another, e.g. in Combined Operations.
- (b) A number of units are operating in the same area, but out of visual distance, and warning received by one unit may be of value to others.

84. The essential difference between the "naval" and "combined" systems is that, in the latter, detections are expressed as geographical positions of the target (using a grid method) instead of as relative bearings and distances of the target from the reporting ship.

Methods of reporting

85. Efficient communications are an indispensable part of the fleet's air cover. Although their provision and organisation are the responsibility of the Communications branch and the precise function of various reporting waves may vary considerably as laid down in detail in Fleet Communication Orders, the methods most usually adopted are described here since they concern the radar and plotting organisations. In all cases, the use of W/T or R/T for reporting radar detections has to be related to the general W/T policy, the use of R/T for directing fighters, and the radar policy.

86. V/S is often used for making first reports, except at night. As a rule it is too slow for a series of detailed reports.

87. The *W/T radar reporting wave* is the standard channel for passing a series of detailed reports. Radar Guardships and standby guardships should keep continuous watch on this wave and use it when ordered to "Commence W/T reporting" by the Senior Officer or the Controlling ship.

88. Other large ships set watch on this wave when the first report of a group of aircraft is received by V/S, or another wave. The object of setting watch is to enable them to intercept reports from guardships and so follow the air situation, but they should only transmit on the radar reporting wave in the circumstances described in *para. 76*, or if controlled to do so.

89. Only the Senior Officer and Controlling ship may ask for repetitions of signals made on the radar reporting wave.

90. It may be convenient to use this wave for passing signals such as those concerning guard duties and radar policy.

91. Small ships (e.g. fleet destroyers) do not normally keep watch on the radar reporting wave owing to lack of personnel.

92. R/T may also be used in connection with radar reporting, especially for passing short orders or information.

93. The *Inter-F.D.O. R/T Wave* may be used by the Controlling ship for passing control orders, asking for supplementary information about raids, and clearing up difficulties such as apparently duplicated reports or doubtful identity. This wave may also be used on occasions for passing detailed reports, although this is not its primary radar function.

94. Control orders and detailed reports when passed by R/T are transmitted in plain language, using the words from the Fighter Director Vocabulary wherever applicable.

95. The control signal "Check" may also be used by R/T meaning "Check whether echo exists bearing distance"

96. The *Fleet R/T wave* (or other R/T wave) is used, as far as radar is concerned, for the following purposes :—

- (a) For broadcasting information on the air situation generally, and in particular about approaching raids and friendly fighters. This broadcast is of particular value to small ships who are not keeping watch on the W/T radar reporting wave.
- (b) By small ships, *e.g.* on a screen, for making urgent first sighting reports in which case the report is made in plain language. Example :—

“ This is GRUMPY in Position Baker, torpedo bombers bearing one two zero, very low, over.” “ Roger, out ” (or repeat back).

97-99.

Technique of reporting and controlling

100. Good reporting calls for strict W/T and R/T discipline, especially when the air density is heavy. Good controlling results from experience and requires frequent exercise (*see Chapter XXII*). The following points should be borne in mind :—

Reporting.

101. (a) Detailed reports made in the W/T reporting code should, for speed, normally contain eight symbols only.

(b) Amplifying information should be signalled every third or fourth report only, and should in any case be confined to information which the Controlling ship cannot extract from the plotting of all reports in their simplest form.

(c) Movements of targets must not be anticipated. “ Forecasting ” is the function of the controlling ship and/or fighter directing ships.

(d) Reports of raids outside 30 miles should be made about every 2 minutes, those of nearer raids about every minute or more often if so ordered.

(e) **Stale reports are not only valueless but misleading and must not be transmitted** if there is more up-to-date information from own ship or other ships.

Controlling.

102. (a) The object, namely to maintain complete cover for height and distance, must always be borne in mind and ships controlled accordingly.

(b) As a rule, the ship first detecting a raid should be allowed to continue reporting it until detection by that ship becomes unreliable, *e.g.* the target enters a gap between lobes or becomes too low or far away, when reporting of the raid may sometimes usefully be transferred to another ship with a different type of set, or to a ship in a better position.

(c) As far as possible, the raids being reported should be evenly distributed between guardships and other ships keeping watch. With type 79 it is not possible efficiently to watch and report more than two raids simultaneously, particularly if they are on opposite bearings. Type 281 or American W.A. sets can handle more raids since P.P.I. display is fitted and it is not necessary to stop the sweep to obtain bearing.

(d) It must be remembered that a ship told to “ hold ” a target will not be watching other sectors. Also the effect of heightfinding is to slow down the effective sweep of type 79 (unless a sector display panel is fitted).

(e) At least one ship should be left as free as possible to maintain all-round watch and report new detections.

(f) The control ship's radar should, if possible, also be kept free to keep a general watch on the situation, confirm identification, and clear up difficulties such as when two ships are apparently reporting the same raid. The accuracy of other ships' reports should also be checked so that any necessary index correction can be applied and the plot kept relatively correct.

(g) The number of raids being reported by W/T should not be allowed to reach a level which causes serious time lag on the reporting wave. If this level is approached the controlling ship may have to take on reporting of some raids in addition to the functions in (f).

(h) Strict control of the radar reporting wave must be exercised, and any tendency to pass “ stale ” reports checked.

(i) In addition to knowing the capabilities and limitations of the different types of radar in use, the controlling officer should endeavour to learn the relative efficiency of different ships. This will help when trying to resolve conflicting reports.

103-104

ALTERNATIVE METHOD OF ORGANISING AND CONTROLLING RADAR FOR AIR COVER, AND REPORTING

105. With the advent of modern radar and communications equipment, as described in *Chapter X*, a different method of organising and controlling radar for air cover, and radar reporting, has been tried and may supersede the methods previously described.

106. The new system, which is described briefly below, has been made possible because of :—

- (a) The fitting of two WA sets and a high-powered WS set in certain ships (e.g. Aircraft Carriers).
- (b) The development of automatically continuously rotating aerials and P.P.I. display, and also sector displays for heightfinding, which obviate the necessity for stopping the sweep in normal circumstances.
- (c) The general fitting of VH/F R/T.

107. **Radar guardship and controlling ship.** A ship fitted with suitable radar sets is detailed as the combined radar guardship and the controlling ship (sometimes called the **radar reporting ship**). This ship is generally an aircraft carrier by day, and a battleship or cruiser by night (in order to rest the carriers' sets). The duties of the reporting ship are as given in *para. 55*, where applicable.

108. A "running situation report" is broadcast of all tracks shown on the reporting ship's main aircraft display plot.

109. **Other ships** keep all-round or sector watch, or a watch between specified ranges, according to the radar policy and orders in force, and plot the tracks received from the reporting ships. They make reports only if they detect a raid which is not being reported, or if information differs about the height, course or size. In such a case, the reporting ship will either :—

- (a) Order the ship to continue reporting the new track.
- (b) Acknowledge the additional information.
- (c) Order the ship to "Hold" or "Watch" or ignore ("Negate") the new track.

110. **Method of reporting.** VH/F R/T is used normally for radar reporting. The Inter-F.D.O. R/T wave and Fleet R/T wave are also used as described in *paras. 93-95*.

111. **Track numbers** are used instead of raid letters, and are allocated by the reporting ship. If a raid splits into several portions the tracks are designated 1A, 1B, etc.

112-124.

ORGANISATION AND CONTROL OF RADAR FOR SURFACE COVER

125. Compared to aircraft warning, the organisation and control of radar for surface cover is usually much less elaborate because :—

- (a) The number of targets is usually fewer.
- (b) Speeds of approach are smaller.
- (c) Maximum detection range is much less.
- (d) At present there are seldom any restrictions on the use of WS sets.

126. Consequently the surface cover provided by WS radar is usually associated with the individual ship rather than with the unit as a whole and radar guardships for surface warning are not usually detailed.

127. Nevertheless, ships have the responsibility of warning others in company of unidentified or hostile surface vessels which they may detect, particularly if they are first detected at close range and/or are closing rapidly. The difference which a few miles in position may make to the radar "vision" of the unit should be remembered, and it should not necessarily be assumed that the Senior Officer or other ships have also detected a new echo.

Surface radar guardships

128. Surface radar guardships may be detailed under the following conditions :—

- (a) If special security is required and it is desired to limit the number of ships transmitting. Ships on the wings, with good ahead arcs, with high sited WS sets and fitted with P.P.I. display are most suitable.
- (b) In persistent low visibility, in order to permit rest and routine maintenance.
- (c) If it is desired to provide special cover in a particular small sector, e.g. E-boats approaching up channel or down moon.
- (d) If other ships have blanked arcs (e.g. the WS sets in some destroyers cannot look right ahead).
- (e) If there are a large number of targets in the area. In this case, sector responsibilities for reporting may be allocated, *vide Chapter XVII*.

129. All round watch should be kept unless otherwise ordered. Radar guardships should report all unidentified detections, or those in their sector of responsibility. Friendly detections should also be reported if they may become a navigational danger.

130. Ships not detailed as guardships but keeping surface warning watch should report similarly if the guardships fail to do so within a reasonable time.

If no guardship is detailed

131. If, as is normally the case, no guardship is detailed, all ships should keep WS watch.

- (a) Provided the radar policy permits.

- (b) When the visibility is less than detection range of the largest type of target, it is desired to detect (*paras. 24 and 25*).

132. Under these circumstances, ships should report all detections which they consider may be hostile.

Methods of sweep

133. Modern WS sets have spinning aerials and P.P.I. display and *all round sweep* is the normal method of operation even if sector responsibility for reporting has been allocated (*para. 109 (e)*). The normal rates of sweep and range scales are given in *Chapter VII*.

134. When, however, *sector responsibility* has been ordered for the purpose in *para 129 (c)*, hand training and "A" display may be used in certain circumstances in order to obtain maximum detection range as explained in *Chapter VII*. The decision whether to use automatic or hand training will depend upon the size of the sector and the speed and detection range of the targets expected.

135. With old WS sets not fitted with P.P.I. display, there is little object in sweeping abaft the beam if the ship's speed exceeds 24 knots.

136. Special rules for sweeping by A/S escorts are contained in *Chapter VIII*.

Controlling ship

137. For surface warning, the controlling ship is always the Senior Officer unless otherwise ordered. The controlling ship will :—

- (a) ensure that surface cover is adequate ;
- (b) detail guardships if necessary ;
- (c) control the reporting wave ;
- (d) if keeping radar watch herself, initiate enemy reports of hostile or unidentified detections. It is important that other ships in the unit should be able to intercept such reports so that they may be assured that the Senior Officer has the target under radar detection.

Codes used for reporting

138. *First reports* are made by means of alarm signal J. (Surface Craft detected by radar, bearing distance) followed by a position if the reporting ships' position may not be generally known to those in Company or to other units who may intercept the report.

139. *Subsequent reports* may be made in a similar manner (as "amplifying reports") or alternatively by means of the "Code for radar reports of Surface Contacts" (*F.S.B. Article 148B*). This code is the surface counterpart of the air reporting code (*Article 148A*), and is particularly suitable when there are several targets under report. It includes a number of amplifying signals, and the necessary control signals. It also includes certain directing signals (*see para. 142*).

140. *Positions* are signalled in the normal manner except when co-operating with other services or when shore radar reports are also being used. In this case, a grid system is normally used.

Method used for reporting

141. Unless special arrangements are necessary (as in the case of combined operations, *Chapter XVII*) the normal intercommunication wave of the unit is used for reporting surface detections, subject, of course, to the W/T policy in force.

CONTROLLED SURFACE INTERCEPTION

142. As explained in *Chapter VII, paras. 47-48*, WS sets may be used to direct smaller vessels (*e.g.* A/S escorts or M.G.B.'s) on to a target not yet detected by the small ships' radar. The directing ship is analogous to a Fighter Directing ship and may either use directing signals from the code in *F.S.B. Article 148B*, or plain language, R/T.

143-144.

I.F.F. AND RADAR BEACON STATES AND GUARDSHIPS

145. The occasions when various I.F.F. and Radar Beacon States (Policies) should be ordered or adopted are given in *Chapter XIV*.

146. When their use is permitted, the Senior Officer should detail I.F.F. and Radar Beacon Guardships within each unit. In the absence of a guard signal, the Senior Officer's ship will herself assume these duties.

147. The object of detailing guardships in a unit is to avoid unnecessarily cluttering radar displays, but ships other than the guard may switch on their own I.F.F. or Radar Beacon at any time if it is considered necessary to do so, *e.g.* :—

- (a) I.F.F.
 - (i) if the guardships' I.F.F. appears to be defective.
 - (ii) in night action ;
 - (iii) on parting company temporarily (or permanently).

(b) Radar Beacons.

If it is necessary for aircraft to distinguish a particular ship in the unit, *e.g.* if several aircraft carriers are operating in company.

148. **I.F.F. Codes.** Under certain circumstances the Senior Officer may require to allocate special I.F.F. Codes, *vide Chapter XIV, paras. 58-60.*

149.

CONTROL OF R.C.M.

150. The use of counter-measures to enemy radar (*e.g.* jamming and "window") is described in *Chapter XV*, and at sea these are usually confined to spoiling the enemy's surface warning (tactical) and gunnery radar.

151. The Senior Officer will be responsible for co-ordinating and controlling tactical counter-measures. He may also control the operation of jamming sets against enemy gunnery radar, but if no orders are received ships may carry out barrage jamming as soon as the enemy opens fire, as explained in *Chapter XV, para. 34*, sets being staggered in wavelength.

152-154.

INSTRUCTIONS APPLICABLE TO ALL RADAR SETS**Most appropriate set to be used**

155. When detailed as radar guardship, a ship should use the most appropriate set fitted whether for high aircraft cover, or low aircraft or surface cover. If the most appropriate set is not available, the fact should be reported.

Breakdowns

156. Radar Guardships must report if radar breaks down stating the expected delay in order that another guardship may be detailed as necessary, to preserve reliable cover.

157. Other ships should not normally report breakdowns at night, or by day if the period out of action is unlikely to exceed one hour. Judgment in this matter is, however, necessary, *e.g.* if the WS set in a cruiser on an extended screen breaks down at night it may be advisable to report the fact at once, since the efficiency of search is at once reduced and a redistribution of the screen may be necessary.

Periods for rest and routine maintenance

158. Ships should take the opportunity, when not detailed as guardships, for resting equipment and personnel and also for carrying out the necessary routine maintenance tests. In hot climates, a period of rest may also be required to allow radar offices to cool down.

159. As a rule, WS sets should be rested by day and WA sets by night.

Signals concerning radar

160. It is advisable to keep in the Operations Room and A.D.R. an extract of the signals and codes most commonly used in conjunction with radar, *vide the Frontispiece, Table I.*

Ceasing guard duty

161. Radar Guardships may cease guard duty :—

- (a) When radar silence is ordered, but in the absence of other orders, guard duties are resumed when silence is relaxed.
- (b) If ordered to cease watch, or when a signal is received detailing new guardships.
- (c) On anchoring or parting company.

Ceasing watch

162. Ships not detailed as guardships may cease radar watch on anchoring or, if radar is not required, on parting company.

CHAPTER XX

EMPLOYMENT OF RADAR IN HARBOUR

EMPLOYMENT OF RADAR IN DEFENDED HARBOURS

The responsibility for providing radar cover in defended harbours lies with the R.A.F. or Army, as described in *Chapter XVI*, and in the majority of such harbours the shore radar system is adequate so that radar guardships are not normally required.

2. Time spent in harbour can and should therefore be devoted, as far as radar is concerned, principally to maintenance and training, so that when ships proceed to sea their radar will be working and will be operated as efficiently as possible.

3. Maintenance and repair work should be put in hand as necessary, but if standard radar exercises or other exercises involving the use of radar are ordered by the Senior Officer, permission to be excused using radar must previously be requested if necessary.

A.A. guardship and radar lookout

4. A.A. Gunfire from the fleet is generally used to augment the shore defences, and an A.A. Guardship is normally detailed. The A.A. Guardship should use her own radar (WA, WS and T.I. Sets) as an aid to target indication, keeping all-round watch. This is termed "Radar Lookout." If the A.A. Guardship's WA radar is out of action due to maintenance requirements, another ship may be detailed to keep a radar lookout for her.

5. Although the Radar Lookout ship has not the full responsibilities of a radar guardship at sea (*Chapter XIX*) she should report to the Senior Officer if one or more groups of unidentified aircraft are detected provided that:—

- (a) They are not the subject of a Current Air warning or notice from the shore organisation.
- (b) Their movements indicate possibility of hostile intent.

6. If the Senior Officer is connected by L/T and if time permits, he should generally check the report with the local Sector or Gun Operations Room before taking further action, as the S.O.R. should be acquainted with the air situation as a whole including the movements of friendly aircraft.

7. Due to land echoes and the necessity of confirming hostile identity, the warning given by ships in defended harbours is likely to be short. The use of the siren or gunfire to attract attention is useful.

Other ships

8. Other ships will not normally keep radar watch in harbour, but in the event of air-raided warning or notice "Yellow" appropriate radar should be switched on if available.

HARBOURS WHERE THE SHORE RADAR WARNING SYSTEM IS INCOMPLETE

9. In harbours where the shore radar system does not give adequate cover, it may be necessary for ships' radar to augment it, and in this case radar guardships should be detailed.

10. It will generally be best for the radar guardship or ships to work directly with and under the control of the local Sector Operations Room, communicating by L/T if possible. Reports to the S.O.R. should be made in "Combined Air Warning Code" using grid positions.

11. In addition, however, reports should be made to the Senior Officer as in *para. 5*.

UNDEFENDED HARBOURS

12. In harbours where there is no efficient shore radar warning system, air and surface cover must be provided by ships present.

13. The organisation and control should be the same as that used at sea (*Chapter XIX*) except that there will be greater emphasis on the need for rest and maintenance. For this reason, ships to be detailed as radar guardships should receive as much warning as possible, and ships should not normally keep watch unless detailed for guard duties.

SECURITY

14. In harbour it is not usual to impose any restrictions on the use of radar or the associated reporting waves. In special cases, such as a new or advanced base, the need for security (with a corresponding loss of radar cover) may have to be considered, and if restrictions are necessary the Senior Officer will promulgate a Radar Policy.

BERTHING OF SHIPS TO AVOID LAND ECHOES AND BLANKING

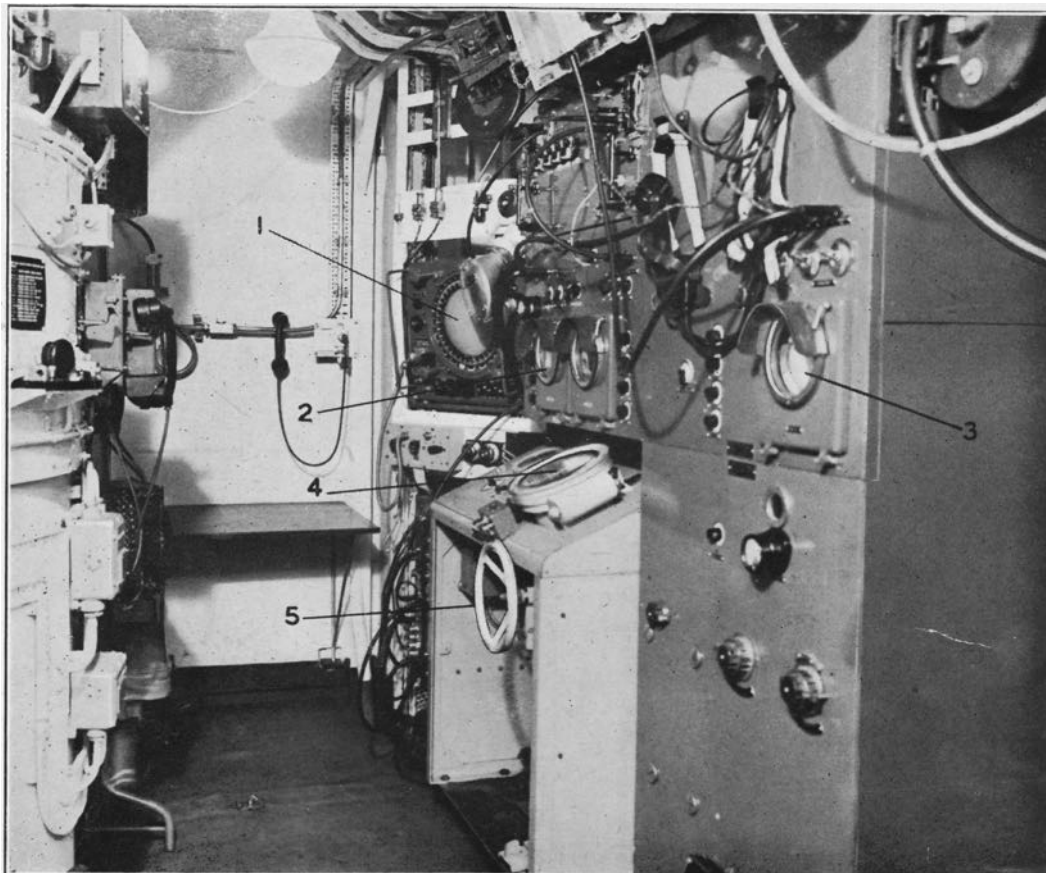
15. Land echoes in harbour are always likely to be troublesome, and this factor must always be considered when selecting or berthing radar guardships.

16. Where land echoes are bad, it may be necessary to resort to the use of one or more types 277 elevated as necessary (*Chapter X, para. 45*), and it may be necessary for WA sets to keep watch on short scale (*Chapter X, para. 44*).

17. Where surface cover is required, e.g. against E-boat attack, radar guardships must also be berthed so as to avoid being blanked by other ships in the anchorage. In addition, reliability of surface cover will not be attained if small craft, ships boats, etc., not fitted with I.F.F. are allowed to move about the anchorage at night, and suitable restrictions should be imposed.

AIRCRAFT PLOTS

18. It will be of assistance, particularly to guardships, if the general configuration of the land and the grid system in force ashore are superimposed on aircraft plots in harbour.



PHOTOGRAPH 74—*W.A. type 281 B receiving office* showing :—

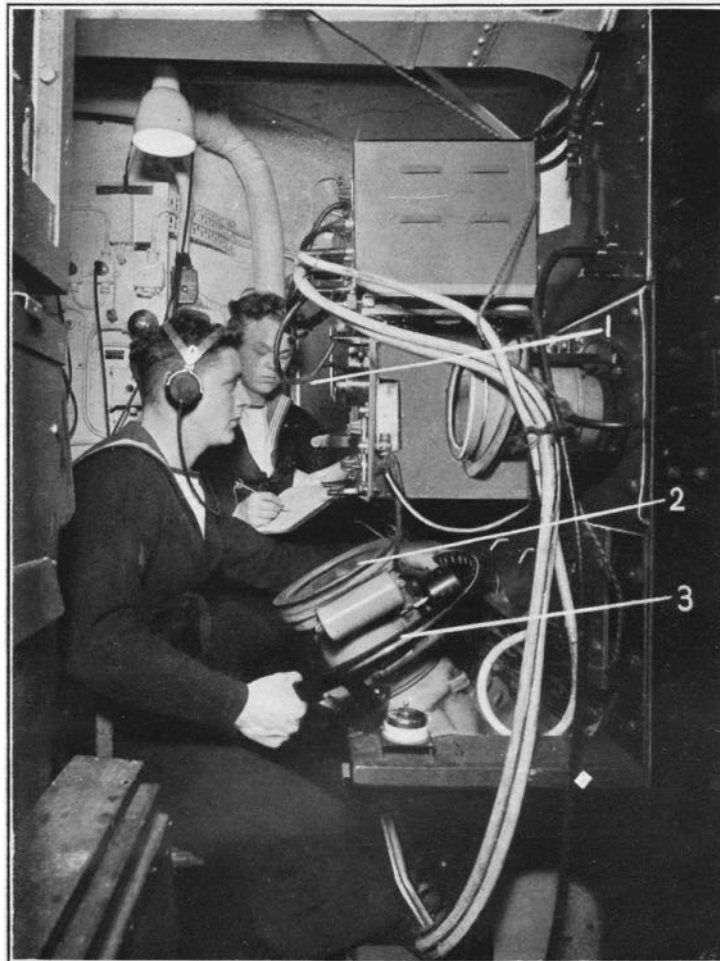
- 1.—P.P.I. display.
- 2.—“A” displays.
- 3.—Accurate ranging “A” display (now obsolete).
- 4.—Aerial bearing indicator.
- 5.—Aerial training control handwheel.

PART IV

MISCELLANEOUS RADAR SUBJECTS

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PHOTOGRAPH 75—*W.A. type 279 receiving office* showing :—

- 1.—“A” display.
- 2.—Aerial bearing indicator and angle-dividing device.
- 3.—Aerial training handwheel.

The operator is training the aerial and watching the “A” display.
The second operator is logging the reports made.

CHAPTER XXI

PERSONNEL AND INTERNAL ORGANISATION, MAINTENANCE,
SECURITY

STATUS AND DUTIES OF OFFICERS AND RATINGS

1. The fitting of radar in the Fleet has called for progressively larger numbers of watch-keeping ratings, who were provided initially as a "Radar Operator" branch and formed a specialised section of the Communications Branch. Owing to the large numbers involved, and the fact that little watchkeeping is carried out in harbour, it became apparent that harbour employment on other duties than radar was essential and accordingly, in November, 1942, all new entries to the branch were trained as seamen. In February, 1943, the branch started re-organisation on a seaman basis, and in October, 1943, it was decided to introduce the non-substantive rates of Radar Control rating and Radar Plot rating, which became effective on 1st March, 1944.

2. The decision to reform the branch on a proper seaman basis, with "Radar Control" and "Radar Plotting" non-substantive rates, was also due to the following considerations:—

(a) The flat rate of 3d. a day radar allowance for all ratings offered little inducement to advancement though this was offset somewhat by the rapid advancement of ratings to Leading Seaman Radar and P.O. Radar.

(b) Operators tended to lack "sea-sense" which showed itself particularly in their difficulty in appreciating the difference between true and relative bearings when making reports.

(c) Finally—and most important—experience with the old "aircraft plot" had shown the value of the men at both ends of a telephone having an equally good appreciation of the capabilities and limitations of radar, and WA operators were becoming widely employed as aircraft plotters for this reason. It was considered that, on the warning side, the same argument applied to WS sets and the "Tactical Plot." On the gunnery side, the fire control organisations were becoming increasingly dependent on radar information, and indeed the majority of ranging, training and spotting displays are now fitted in the T.S., H.A.C.P. or director and not in the radar office at all. It was clear that there was every advantage in having the same breed of rating to work (for example) the spotting plot and the radar spotting display, and that they should be interchangeable.

THE R.C.-R.P. BRANCH

3. In some ways it might have been desirable to have had a rating who was trained in radar and all of its associated functions, but lack of training time and the limitations of the human brain clearly precluded this. It was decided instead that ratings should divide into two non-substantive branches, viz. :—

(a) **Radar Control (R.C.) ratings**, to man

- (i) All gunnery radar sets.
- (ii) Certain positions in the T.S., H.A.C.P., and T.I. Room.

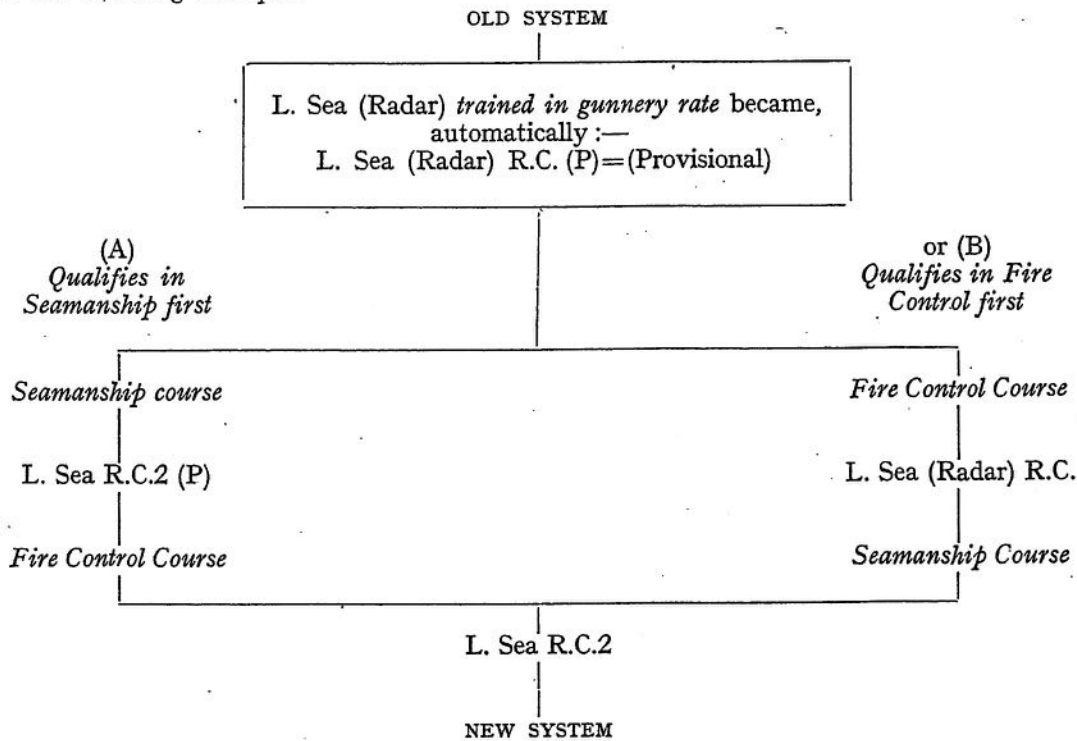
(b) **Radar Plot (R.P.) ratings**, to man

- (i) All warning radar sets.
- (ii) Plotting and internal communication positions in the Action Information centre (except the T.I. Room).

4. This is now the established policy. New entry ratings, having qualified in Seamanship, undergo an initial basic radar course on either warning or fire control radar sets. They then carry out a further course in Plotting or Gunnery schools and qualify as R.P.3 or R.C.3 non-substantive ratings. Thereafter, their progress is on exactly parallel lines to other seamen with non-substantive rates, e.g. A.A. or Q.R.; that is to say, an R.C.3 rating may advance to R.C.2, R.C.1 and Gunners Mate subject to passing the necessary examinations at the Radar and Gunnery schools (or in some cases afloat). On the substantive side the progress to higher rate is also identical, i.e. subject to passing the necessary seamanship examinations, etc., the avenue is open to Leading Seaman, P.O., C.P.O. and to Warrant and Commissioned rank. Full details are contained in A.F.O.'s and in B.R. 1066.

The changeover from the old to the new system

5. The changeover from the old system is being carried out by allocating provisional R.C. or R.P. rates to ratings of the old radar branch according to whether their initial training and subsequent experience was in gunnery or warning radar. Confirmation in non-substantive rate is subject to a course at the Radar and Gunnery (or Plotting) Schools. In addition, of course, it is necessary to qualify a very large number of ratings in seamanship. In practice a rating may qualify in seamanship before receiving non-substantive confirmation, or *vice versa*, and his progress in conversion may therefore take one of two paths as illustrated in the following example :—



In two stages therefore he has dropped the title "Radar" and assumed the full non-substantive rate of R.C.2. Full details for each rating, and the procedure in the case of failures, are contained in A.F.O.'s and in BR 1066.

How executive and specialist officers can help

6. It is of great importance to get the new twin branch on its feet as soon as possible, and in particular to expedite the changeover process in the case of ratings of the former radar branch. Executive and specialist officers can assist in this by :—

- (a) pressing on with seamanship courses ;
- (b) encouraging men to qualify on board for the 3rd class non-substantive rate, where this is allowed ;
- (c) ensuring that the most suitable men are recommended for high non-substantive rate ; and are released for shore courses as necessary.

Men unable to turn over to the new branch

7. In the early days of the radar branch the eyesight requirements were not so stringent as they are for the seaman branch and for this and other reasons it happens that a number of the old branch are ineligible for transfer to the new. These ratings form a special case and will continue to be known as L. Seaman (Radar), P.O. (Radar), etc., with the addition of "R.C." or "R.P." as appropriate after qualification in Fire Control or Plotting. They will not qualify in seamanship, and will therefore not become full seamen.

Acting operators

8. In the circumstances explained in *para. 22* certain small ships may employ acting radar operators for watchkeeping purposes. Such ratings do not form part of the R.C.—R.P. branch but they are clearly a good source from which they can later join it, if recommended.

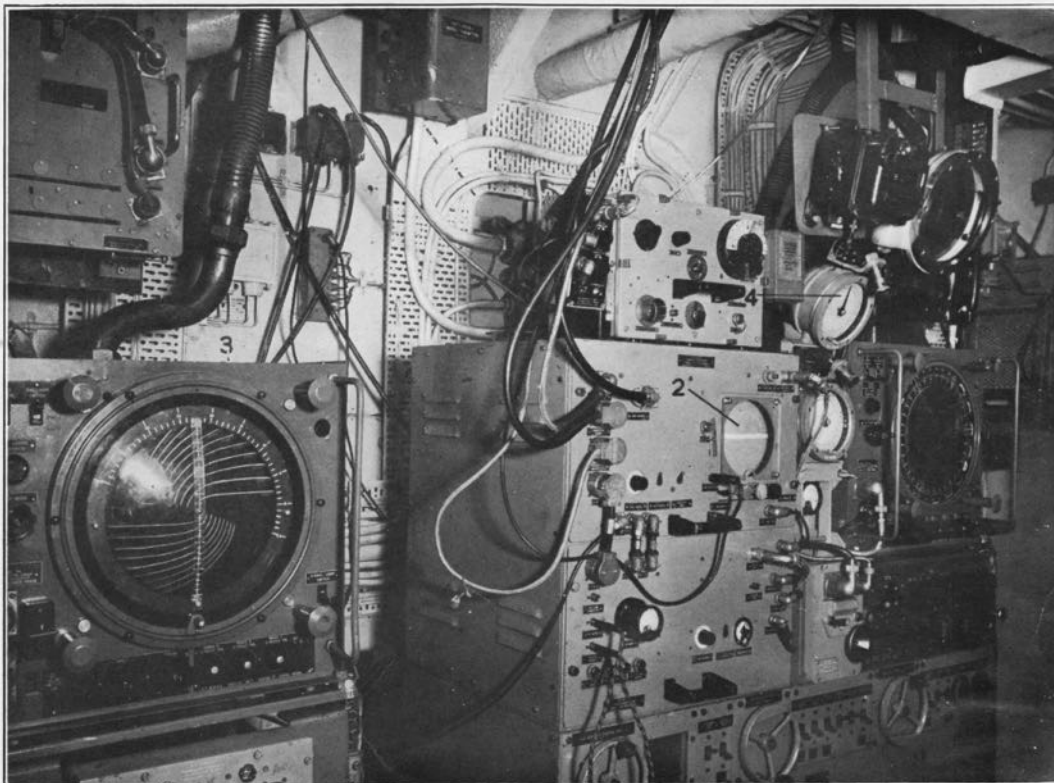
RADIO MECHANICS

9. Radar operators are primarily operational and not technical. In order to undertake maintenance of the extremely complicated apparatus used in radar, as well as for W/T, the Radio Mechanic Branch was formed. As with operators, it was necessary to subdivide the branch and ratings are at present trained in the following categories :—

R = Radar in big ships.

W = W/T and Radar in small ships (up to date their radar duties have predominated), and Fighter Direction R/T equipment in larger ships.

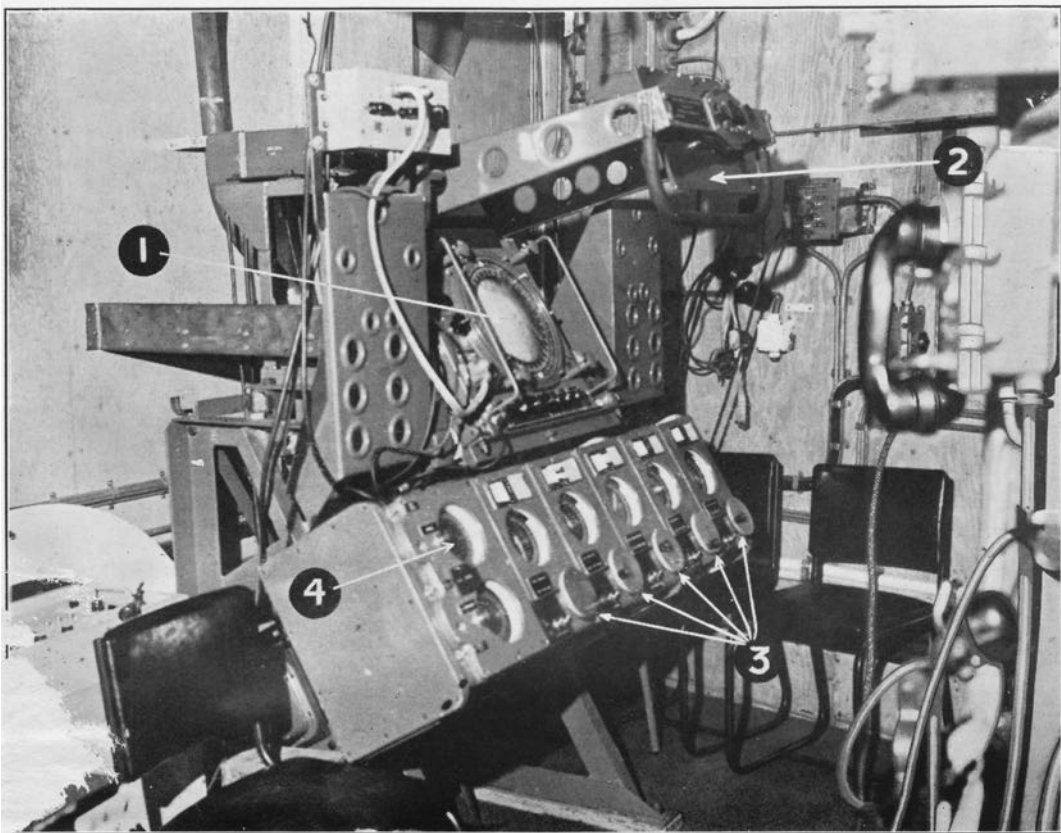
S = W/T in shore stations.



PHOTOGRAPH 76—*W.S. type 277 office* in a large ship, showing :—

- 1.—P.P.I. display.
- 2.—“A” display.
- 3.—H.P.I.
- 4.—Aerial bearing indicator.

The Sector Selector Displays are not shown.



PHOTOGRAPH 77—W.C. type 293 target indicating office showing:—

- 1.—P.P.I display.
- 2.—Mirrors for projecting optical bearing lines onto face of P.P.I.
- 3.—Handwheels for operating optical system and transmitting bearings to out position.
- 4.—Aerial bearing indicator.

10. It is under consideration to regroup the categories as follows :-

W/T = W/T in ships and shore stations.

R = Radar in big ships.

WR = W/T and Radar in small ships.

11. In the former case the higher ratings, or a proportion of them, undergo a course in the "opposite" subject and are then given the category "**C**," e.g., C.P.O. Radio Mechanic (C). In the latter case it is under consideration to confine the rating of Chief Radio Mechanic to W/T or Radar, in which case the opposite subject will not be taught.

12. A Radio Mechanic is an artisan and goes to sea as a Leading rate. After a year's experience, and subject to a certificate of efficiency from a qualified Communications or Radar Officer, he may be rated Acting Petty Officer and confirmed after a further year. It is under consideration to reorganise the Radio Mechanic branch on the same lines as other artisans by the introduction of 5th class, acting 4th class, 4th class, etc., and Chief Radio Mechanic.

13. It should be appreciated that owing to the short time available for training in war time, and the fact that most mechanics had no connection with radio before they entered, the Radio Mechanic is not a radio engineer and lacks practical experience at sea. His duties are primarily to carry out routine maintenance tests, fault finding, and fault mending: in these duties he is the radar officer's assistant. It should be noted that the Radio Mechanic (W) (or WR in future) is usually on his own and without the immediate guidance of a Radar Officer; the responsibilities of this category are therefore considerable.

RADAR OFFICERS

14. Radar Officers were originally trained and provided to make radar work, *i.e.*, primarily as technical officers, but owing to the widespread lack of knowledge about radar in the fleet radar officers afloat soon added a much more operational role to their duties, as advisers on the use of radar. In this they have done much valuable service, but the time will come (if it has not come already) when the specialist "users" of radar (G, N, F.D., A/S, and T) must take direct control of the application and development of radar in their particular sphere: indeed, delay in assumption of this duty is likely to have ill effects, for radar is not itself a weapon but rather an important adjunct to nearly all weapons.

15. The tendency therefore will be for radar officers to resume their original technical function, acting of course as technical advisers to the "user" branches and being responsible also for the purely technical side of the training of operators and their supervision in radar offices, and for the training and supervision of radio mechanics.

16. Ultimately, also, radar officers will doubtless become responsible for the technical working and maintenance of all radio equipment, *i.e.*, both for communications W/T and radar equipment, and will thus become "Radio Officers." A start towards this objective has already been made (*vide* A.F.O.'s), but its full realisation is dependent on being able to give Radar Officers the necessary training to fit them for the additional responsibilities.

17. In the meanwhile the exact proportion of a radar officer's radar duties, as between "operational" and "technical," will depend upon personalities and the extent to which the "users" can incorporate radar in their organisations.

18. As with mechanics, the war-time training of radar officers is all too short, and experience has to be gained at sea. After qualification it is usual for officers to join, and stay in, one of the following categories:—

- (a) Large ships, starting as 2nd radar officer.
- (b) Escort groups.
- (c) Coastal Forces.
- (d) Ship fitting.

19. In small ships who do not carry a qualified radar officer it is the practice to detail an officer to act as "Radar Officer" to co-ordinate the use of radar and look after the ratings.

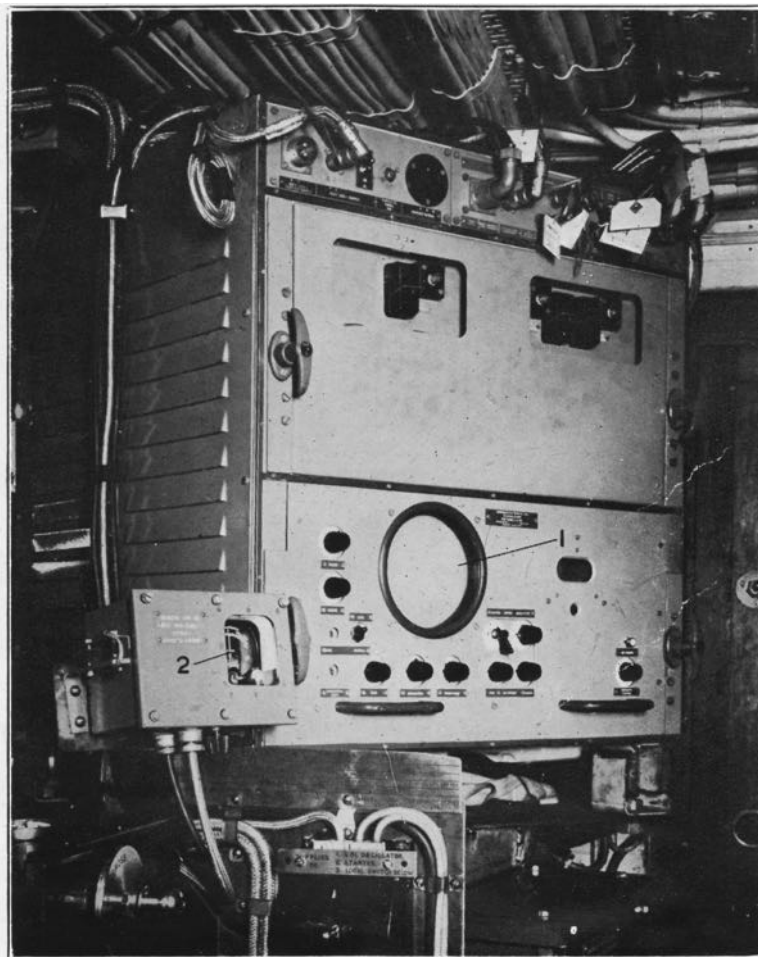
20. In fleets and in certain squadrons a qualified radar officer is appointed as Fleet (or Squadron) Radar Officer. This officer's duties are also subject to the remarks in *paras. 14 to 16*, but in addition he has to undertake co-ordination of radar policy and use, and exercises.

COMPLEMENTS, STATIONING, AND DIVISIONAL ORGANISATION

Radar operators

21. The complements of R.C. and R.P. ratings allowed are laid down in C.A.F.O.'s. They are based on the following considerations:—

- (a) *At action.* It is necessary to man fully all warning and gunnery radar sets and in addition the necessary Fire Control and A.I.C. positions.
- (b) *At cruising and defence stations* warning radar sets must be manned continuously for long periods and three watches are required. (The minimum number per watch is two so that operators and loggers can change round every half hour to avoid eye-strain). Gunnery radar sets on the other hand are not used continuously and are therefore generally manned in two watches in conformity with their associated fire control organisation. Close range (GC) gunnery radar sets are not manned: this provides a number of R.C. ratings who are available as watchkeepers on the warning sets.



PHOTOGRAPH 78—G.S. type 274. Remote training tube and meter in the T.S. showing :—

- 1.—Training tube ("A" display).
- 2.—Training Meter.

22. Attention is drawn to the fact that the onus of applying for R.C. and R.P. ratings now lies on the ship, and operators are not provided automatically as heretofore. The procedure is to work out the number of ratings allowed (a) at action and (b) at cruising stations. The larger number is the authorised complement, and if (b) exceeds (a) R.P. ratings are allowed in lieu of "Seaman (other)" except in small ships where on account of space considerations acting operators are employed and paid.

23. **Divisional organisation and messing.** Formerly radar operators formed part of the Communications Division, or formed a separate Division under either the Radar Officer or an executive officer. With the inauguration of the new scheme it is logical that R.C. ratings should be split amongst the seamen divisions and mess with the other ratings in their fire control team. Similarly R.P. ratings should mess with the other seamen of their division; if possible their mess should be near the A.I.C. and warning radar offices.

Radio Mechanics

24. Radio mechanic complements are laid down in C.A.F.O's. With the increasing complexity and numbers of radar sets fitted a considerable increase in complements may become necessary.

25. At action stations radio mechanics should be split up between the principal radar offices and positions, whence they can proceed to other positions if required. Typical positions would be R.D.R., WA set, WS set, WC (T.I.) set, and GS set.

26. As artisans, radio mechanics should mess in the artisans' mess.

Radar Officers

27. Radar Officer complements are laid down in C.A.F.O's. In larger ships, where an R.D.R. is fitted, the Radar Officer's normal action station will be in this position. Alternatively he may be in the most important radar office, according to the operation in progress. It is important however that the Radar Officer should not be tied down to any one position, e.g., by carrying out heightfinding or plotting duties, since he may be needed in another part of the ship should technical trouble occur.

28. Where a second radar officer is carried he should preferably be stationed at action in a position remote from the first.

MISCELLANEOUS POINTS ABOUT OPERATORS

Harbour duties

29. At sea all radar operators will be engaged in watchkeeping. In harbour it will be to the general advantage, as previously explained, that they should be employed as much as possible as seamen. It will, however, be necessary to detail a number for cleaning, repair and maintenance duties, to work under the radar officer. This standing party is analogous to the Torpedo party, and it is false economy to reduce its size or withhold it from its duties under normal conditions.

Cleanliness of offices

30. Radar equipment is now sufficiently stabilised to render it unnecessary for radar offices to be less clean than any others, and dirt and dust have a bad electrical as well as a bad psychological effect on performance and operation. Radar offices should always be included in "Rounds."

Performance of radar sets

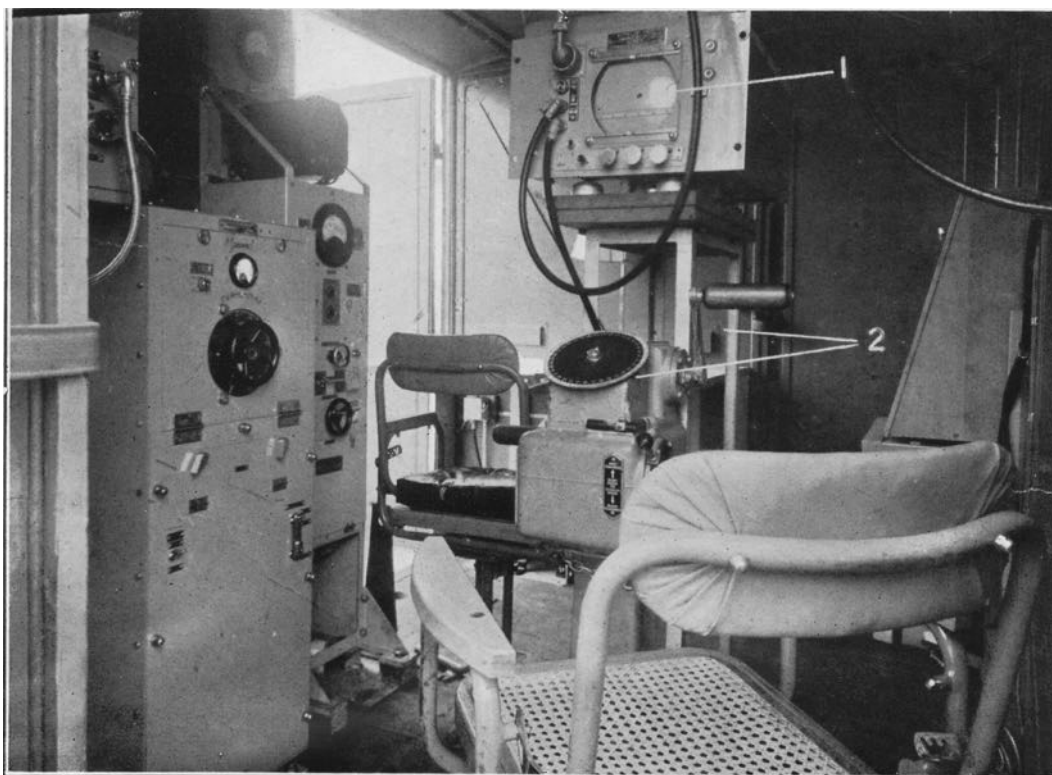
31. The acid test of good maintenance is the actual performance of radar against targets of various size, and the operator is in the best position for observing this. Operators should therefore be fully conversant with the performance to be expected from their set and encouraged to report when this performance is not being achieved (as well as when it is exceeded). The target figures for each set (*vide Appendix I*) should be kept displayed in the radar office except when dockyard workmen, etc., are present. Details of ranges, type and height, etc., of targets actually detected should be noted in the operator's log (*Chapter XXII*) for future record and analysis.

Effect of radar watchkeeping. Eyesight tests

32. Constant alert watchkeeping imposes a considerable mental and physical strain, and for this reason operators should not continuously watch a radar display for more than half an hour in normal circumstances, but should change round with the logger or communication number.

33. Provided this is done there is no danger of eyestrain. As an additional precaution, radar operators should be given eyesight tests half yearly as laid down in A.F.O's.

34. The superstition, at one time widespread, that radar waves act to the detriment of manly attributes is without foundation.



PHOTOGRAPH 79—*Mobile shore Radar station. Operating Cabin showing :—*
1.—“A” display (a P.P.I. would now also be fitted).
2.—Aerial training gear and indicator.

MAINTENANCE

40. Maintenance is a dull sounding subject but with the great expansion in the numbers of sets fitted, and their complexity, it is one of the most important aspects of radar to-day. For even the best operating is of no use if the set is not working to fair efficiency, as many are not. The subject of radio maintenance is therefore one which should engage the attention of every user of radar, *i.e.*, every general service officer, and any help he can give the maintenance staff will be amply repaid by results.

41. The object of maintenance afloat is to prevent faults arising and prevent radar sets gradually (or suddenly) losing their efficiency. The method of achieving this is to carry out **routine tests**, *i.e.*, to inspect and measure regularly the various valves, voltages, currents, etc., so that if a defect begins to show itself steps can be taken before an actual breakdown occurs.

Radio equipment log

42. These routine tests must be carried out regularly, and the results (not just "ticks") noted for each set in the Radio Equipment Log in which the target figures and tolerances for each set are to be found, together with the actual figures taken by the fitting out officer. A summary of repairs carried out is also entered in the log. The log is signed by the Radar Officer weekly and by the Captain monthly.

Assistance by radar operators in maintenance

43. Owing to the large number of sets fitted and the relatively small complements of radio mechanics, it is necessary for radar operators to assist mechanics by carrying out the simpler tests, *e.g.*, those which do not involve complications such as calibration or re-tuning, and this is one of the reasons why a standing party is required in harbour (*para. 29*).

44. Many operators show an aptitude for this work and their knowledge of the simpler forms of maintenance, including aerial repair work, may reap dividends in action. Care must be taken however that operators, and especially those not detailed to help mechanics, do not attempt to supplant the mechanic. Much trouble has been caused in the past, and much equipment damaged, by unskilled and unsupervised attention of this sort.

Responsibilities of and assistance by other branches

45. The responsibility for alternators, low power internal communications and aerial pedestals (mechanical and electrical parts, etc.) lies with the torpedo branch, and extra staff which may include E.A.'s, L.T.O.'s. and S.T.'s. are allowed in complement to cater for this as laid down in A.F.O.'s. The assistance of E.A.'s. may also be necessary to execute delicate or complicated repairs beyond the capability of the mechanic.

46. Similarly the ordnance branch are responsible for the mechanical parts of internal gunnery communications such as R.T.U.'s.

Reporting defects

47. Even though the routine tests are methodically carried out defects inevitably occur in radar equipment and these may cause a partial or complete breakdown of the set. These defects are usually caused either by valves burning out, by soldered joints becoming "dry" and shaking loose, or by the failure of some particular item whose design and production has been hurried by war-time needs.

48. Whatever the cause it is most important, after remedying the defect to report its occurrence and details to the Admiralty Signal Establishment on Form S1183. Only by so doing can expeditious steps be taken to improve the design and, in the meanwhile, increase the supply of spares. Subsequently a fuller report should be made, either as a special report or in Routine report No. 2 (*Chapter XXIV*).

Radio Maintenance Room

49. It is now approved policy to provide in each large ship a radio maintenance room where W/T and radar tests and repairs can be carried out under favourable conditions. In the case of certain new radar sets such as type 262, where the "unit replacement system" has been adopted, the spare units will be kept in the R.M.R. where defective units will be repaired after replacement.

50. Destroyers and smaller ships will not be provided with an R.M.R. Those with sets such as type 262 will have a ready-use store for unit replacement, with a test rack where live tests can be made.

Shore radar organisations

51. Each large port has a shore radar organisation run by the **Port Radar Officer**, who is on the staff of the local Commander-in-Chief or Flag Officer. This may become a "radio" organisation, *i.e.*, embrace both communications and radar equipment, under a "Port Radio Officer."

52. Although the primary duty of the shore organisation is first fitting of equipment, their services are available and should be called upon to deal with defects or maintenance problems outside the capacity of ship staff. It should be remembered that the shore organisations, by the variety of their work, are likely to attain a higher technical standard than is possible in ships: no reluctance should therefore be felt in asking for their services if it is deemed necessary.

53. In addition to the fitting organisations above, the majority of small ships such as destroyer flotillas and escort groups have their centralised maintenance organisations, either in a depot ship or ashore (where in some cases they are combined with the Port fitting organisation).

Performance is the real test

54. Finally it should be stressed again that in spite of the necessity for routine tests and the benefit that is gained from performance meters (where fitted) the final test of efficiency is the performance achieved. It is essential therefore for mechanics, no less than operators, to know the target performance figures given in *Appendix I*.

55-59.

SECURITY

Security classifications

60. The normal security classifications for radar equipment, publications and correspondence are summarised below. Where common sense indicates that a lower grading is permissible, such grading should be applied.

A. Equipment

<i>Types of equipment.</i>	<i>Normal Security grading.</i>
1. Equipment under development	Secret. If however the equipment will perform an operational function for which radar has not previously been used, it may in exceptional cases be graded Top Secret .
2. Equipment in service, including trainers and test gear.	Normally Confidential , but may be Restricted only if the equipment is known to have been captured by the enemy.
3. Enemy equipment	{ (a) if known by the enemy to be in our possession— Restricted . { (b) if this fact may not be known— Secret .

B. Publications and Correspondence

1. Publications on the use of radar, technical handbooks, and performance figures.	The same grading as the equipment to which they refer, <i>i.e.</i> , normally Secret for equipment under development and Confidential for equipment in service.
2. Operating and servicing instructions which do not include details of application or performance.	Restricted .
3. Correspondence and reports	As for B 1 as far as radar is concerned, but if they are part of a report (<i>e.g.</i> , of action) a higher grading may be necessary.

Destruction of radar equipment and publications in emergency

61. In emergency, every endeavour must be made to destroy radar equipment and publications in order to avoid useful information falling into the hands of the enemy. Publications (including radar operators' logs) should be burnt.

62. Equipment should also be destroyed by fire if possible, or alternatively dismantled and the components thrown overboard separately in deep water. It is important to deny the enemy of knowledge of wavelengths and special techniques. Consequently, special attention should be given to aerials, wave guides, wavemeters and components such as magnetrons of whose details and manufacturing technique the enemy may not be aware.

63. I.F.F. sets fitted in naval ships smaller than Corvettes are provided with destructors which should, if necessary, be operated as described in *CB. 04092/44 Section 14*.

CHAPTER XXII

TRAINING AND EXERCISES

1. The need for careful and constant training at sea is as important in radar as in any other branch, and results in action are likely to be in proportion to the attention that has been paid to working up, and continued practice thereafter.
2. Radar training falls into three stages :—
 - (a) Detailed technical training of operators.
 - (b) Training of general service officers.
 - (c) Team training.

DETAILED TECHNICAL TRAINING OF OPERATORS

3. It must be appreciated that newly qualified R.C. and R.P. ratings will have done only short courses at the Radar School (4 weeks) and at the Gunnery or Plotting school (3 weeks). These periods are sufficient for basic training only, and cannot possibly produce a completely trained operator. Training must be completed and experience acquired at sea.
4. In addition, the majority of radar operators at present are H.O. ratings, so that service experience and sea sense may be lacking on joining a ship.
5. Detailed training of R.C. and R.P. ratings in fire control and plotting will be carried out under the direction of the Gunnery Officer and Navigating Officers respectively. As regards the purely technical side, in the radar office itself, *i.e.*, manipulation of controls and reading of the trace, the Radar Officer is responsible, though the actual instruction will normally be carried out by higher R.C. or R.P. ratings.
6. Detailed radar training will take the form of lectures followed by practical training in following echoes, ranging and obtaining bearing and also instruction in classifying echoes. When practising following echoes an inexperienced operator should start with easy conditions, *e.g.*, it is of little value for him to attempt to hold a fast crossing target with a gunnery radar set, and synthetic teachers (*para. 43*) are useful at this stage.
7. Another method of training which has been found of the greatest value, particularly in small ships, is for ratings to close up on the bridge and see the situation for themselves, witnessing the mistakes and omissions of the operator on watch. This procedure also teaches ratings to appreciate the type of information which the bridge primarily requires. In all ships frequent visits of operators, as observers, to the Operations Room and A.D.R. are also of great value.
8. In small ships it will be necessary to call upon the Flotilla or Group Instructor or Radar Officer to carry out detailed technical training, and to visit the ship at subsequent intervals to see that a good standard is being maintained.

TRAINING OF GENERAL SERVICE OFFICERS

9. As has been stressed throughout this Manual, it is impossible for officers to get full value out of radar unless they appreciate its capabilities and limitations, and know the correct procedure. They should also know the operators' difficulties. These remarks apply particularly to officers whose duties are intimately connected with radar such as plotting officers in the A.I.C., the A.D.O. and his assistants, and O.O.W's.
10. A very good practical way of acquiring this knowledge is for officers to keep a short watch in the radar office. If every officer kept even half an hour's watch the general level of radar knowledge and practical realisation of its place in the service would markedly increase.

TEAM TRAINING

11. After detailed technical training, the next step is collective training to ensure that the officers and ratings in the radar offices, fire control organisation and A.I.C. work together as teams.
12. Once again team training should start with comparatively simple exercises, *e.g.*, it is not much use inaugurating the organisation under conditions such as those of a massed aircraft attack.
13. During the course of team training, ratings should change round from time to time, *e.g.*, R.P. ratings in the WA radar office should man the A.D.R. and *vice versa*, to ensure that the requirements of the latter and the difficulties of the former are properly understood. The training of R.C. and R.P. ratings should now make this change round easy, and it will in any case be a necessary part of their experience. It is recommended, however, that changes in action stations should not be made at intervals of less than 6 months.
14. Team training can be carried out in the following ways :—
 - (a) By standard Radar Exercises.
 - (b) During firing practices.
 - (c) *Ad hoc*, by making use of inclination exercises, escorting aircraft, etc.

STANDARD RADAR EXERCISES

15. A number of set-piece standard exercises are contained in BR—" Radar Exercises"—and are classified as follows :—

- A series—Aircraft warning, plotting, and reporting exercises.
- S series—Surface warning, plotting, and reporting exercises.
- H series—Heightfinding calibrations and exercises.
- J series—Counter-measure and anti-jamming exercises.

16. Some of these exercises are suitable for use in harbour in which case they are normally arranged by the Senior Officer. All ships are required to take part unless permission to be excused has previously been obtained on account of maintenance work, ammunitioning ship, etc.

17. The remaining exercises are designed for use at sea and can conveniently be carried out while on passage.

18. It should be emphasised that the primary object of the exercises in B.R.—is to perfect the "mechanics" of plotting and reporting, so that radar may play its part efficiently in tactical and aircraft exercises, and later in action.

Practice firings

19. The associated radar will naturally be used during practice firings, but opportunity should also be taken to exercise "stand-by" sets such as the WA set or other gunnery radar sets in ranging and, if possible, radar spotting.

20. It is also wise to exercise other forms of radio transmission during part of the firing, e.g., by making a dummy enemy report and by transmitting on the fire control wave, and on R/T. This brings to light any mutual interference and enables remedial measures to be taken during the dress rehearsal stage.

21. To enable radar to be fully exercised during gunnery firings, targets have to be fitted with special reflectors. Battle Practice Targets fly balloons with corner reflectors suspended from them. Sleeve targets are fitted with metal-lined or wire mesh "flags" which enable ranges to be taken of the sleeve instead of the towing target. Details are contained in C.B. 4112(I).

"Ad hoc" exercises

22. Numerous other occasions arise when radar teams can be exercised. These include :—

- (a) Inclination exercises.
- (b) When another ship or convoy is met.
- (c) When an A/S air escort or escorting fighters are in company.
- (d) During dummy bombing attacks.

23. In harbour the normal local air activity will often provide good practice in aircraft detection and plotting, and target indication.

REMARKS ON VARIOUS FORMS OF EXERCISES

Aircraft warning and plotting

24. There is usually a very wide difference between the number of aircraft available for exercises and the large forces, both friendly and hostile, that come under detection during a big operation. The result is that the raid handling capacity of the fleet's plotting organisation and the necessary control on the radar reporting wave are sometimes found wanting in action.

25. To counteract this in exercises, it should be arranged that selected ships have ready a number of dummy reports which are used to keep the traffic up to a high level and occasionally to deliberately confuse the situation.

26. One of the chief lessons to be instilled during these exercises is that ships must not transmit stale reports. The exercises are also of great value in giving experience to the controlling ship and remarks on control by an independent experienced ship should be called for where possible.

Surface warning and plotting

27. The remarks above apply also to surface warning and plotting, though in a lesser degree on account of the smaller numbers and slower speeds involved.

28. During surface warning and plotting exercises, it should if possible be arranged that the target moves out of detection range from time to time, in order to exercise picking up procedure including quick estimation of a new target's course and speed.

29. Once confidence in the surface warning and plotting organisation has been obtained by simple exercises, it has been found valuable to carry out "Night Encounter exercises by day" in which the units are manoeuvred entirely on radar information, from the Bridge Plotting Room. The "visibility" and effective blind gunfire range are communicated before the exercise starts.

Navigation

30. The degree of reliability of radar for navigation should be tested in good visibility by calling for reports of prominent headlands, islands, or buoys. If P.P.I. is fitted the changing appearance of the coastline, from different positions, should be observed and noted for future use; while the methods of obtaining a fix from P.P.I., as explained in *Chapter IX*, should frequently be tested.

31-34.

MISCELLANEOUS REMARKS ON TRAINING

Exercising stand-by radar sets

35. As explained in previous chapters, many radar sets can give useful results for purposes other than that for which they are primarily fitted. Examples are the use of the WA set for surface ranging, the use of the GS set for surface warning, and the use of a GA set for limited air cover.

36. In action, breakdown of the main set may necessitate the use of a stand-by and it is therefore essential to work out the necessary organisation and internal communications beforehand and to exercise "breakdowns" regularly. It is suggested that breakdown should form part of some practice firings once efficiency with the primary set has been achieved.

Proximity to land

37. Nearly all radar sets suffer from land echoes and under normal circumstances it is therefore important that exercises involving the use of radar should be carried out sufficiently far from the coast, or in a position from which land echoes will interfere least. This applies particularly when the WA set is being used, *e.g.*, for massed aircraft attacks or fighter direction exercises, since side and back echoes from high land are received up to 20 miles or more.

38. In harbour radar exercises, the effect of land echoes must, of course, be accepted but the course of the target should be chosen so that land echoes will be least troublesome.

39. The remarks in *para. 37* do not apply when working up for an amphibious operation. In this case, once efficiency under normal conditions has been achieved, interference from land echoes is actually desirable since it will represent the actual conditions to be expected and will teach operators to carry on under difficulties, and also warn staff officers of the reduced radar cover under such conditions.

40. Heightfinding calibration exercises with WA sets will seldom be satisfactory if carried out in harbour or near land. Not only will land echoes make it difficult to hold the target and measure echo heights but the vertical coverage diagram will be distorted and consequently the calibration will be inaccurate.

Records of radar exercises

41. Where records are called for it is important that they should be forwarded quickly so that they can be analysed and returned before the various incidents and mistakes have been forgotten. Speed in rendering reports is much more important than neatness.

42. Unless otherwise stated plots of aircraft should be made on a scale of 4 miles to the inch, and plots of surface vessels on Chart 5004 on a scale of 2 miles to the inch, a pencil tracing only being forwarded if records are required. If reporting is exercised, plots of own ship's detections should be shown in red and plots of intercepted reports in other suitable colours.

Synthetic Teachers

43. Synthetic teachers have been developed and are supplied to Cruisers and above, Depot ships, and shore training establishments as follows:—

- (a) **Teacher outfit HRA.** A simple teacher for WS sets.
- (b) **Teacher outfit HRB.** A teacher for gunnery radar sets to exercise ranging, training, and radar spotting.
- (c) **Teacher outfit HRD.** A teacher for warning radar sets (including WA sets) giving a wider variety of echoes than HRA.

44. These teachers are primarily for technical training of the inexperienced operator in operating his set and range transmission units, and are of most value in harbour or ashore. At present they are of little value for "team training": one reason for this is the fact that targets follow a spiral instead of a straight course.

45-49.

COURSES ASHORE FOR GENERAL SERVICE OFFICERS

50. To meet the needs of general service officers who have had no experience of radar, or who wish to be brought up-to-date, short courses in the use of radar are held weekly at the Signal Section, R.N. Barracks, Portsmouth, under the direction of the Captain Radar Training. These are attended by officers of all ranks, and are particularly valuable for Commanding Officers and Watchkeeping Officers of small ships who may not have qualified specialist and Radar Officers to advise them.

Applications should be made as laid down in A.F.O's.

51. For those officers who cannot conveniently attend one of the above courses, facilities are available at Sherbrooke House, Glasgow.

CHAPTER XXIII

RADAR OPERATING PROCEDURE AND DRILL

No organisation can run efficiently without good drill. It is necessary to insist on correct radar operating procedure (*i.e.*, drill), both by operators and by the controlling positions.* Slack or incorrect drill will slow up reporting and will usually lead to error and confusion.

2. Radar operating procedure is laid down in :—

B.R.—Operating procedure for warning radar (which will supersede *C.B. 4180A*).

B.R. 984—Drill for gunnery radar sets (which superseded *C.B. 4180B*).

3. The following summary of the main points to remember refers to warning sets. The same principles apply to gunnery radar sets, but additional control orders are used, *vide* Table 3 and *B.R. 984*.

CLOSING UP

4. When ordered to close up the operator warms up his set (which takes from 5 to 20 minutes, depending on the type), tests communications and lines up instruments. When ready, he reports "**Ready to operate.**" The Control Officer then orders "**Commence operating.**" No transmission is to take place until this order has been given, or unless ordered to "**Test transmitting.**"

INFORMATION TO BE GIVEN TO THE RADAR OFFICE

5. At the same time the Control Officer must give the following information to the radar office :—

(a) **The type of sweep** to be carried out, whether all round or sector. An all round sweep is the normal and is assumed in the absence of other orders.

(b) **The rate of sweep** if other than normal. Normal rates of sweep are :—

WA sets, type 79	...	...	...	...	2 r.p.m.
281	...	...	...	...	2 r.p.m. (4 r.p.m. when conducting fighter interception).
WS sets, type 271/2/3 without P.P.I.	...	...	...	...	$\frac{1}{2}$ r.p.m. ($\frac{1}{4}$ r.p.m. in rough weather when searching for small targets).
271/2/3 with P.P.I.	...	...	...	...	1 r.p.m.
277	...	...	...	...	6 r.p.m.
WC sets, type 276/293 used for warning	...	...	...	...	$7\frac{1}{2}$ r.p.m.
276/293 used for target indication	...	...	...	...	15 r.p.m.
291	...	...	...	...	1 r.p.m.

(c) **The scale to use** if other than normal. Normal scales are :—

WA sets	...	...	...	...	Long scale.
WS sets in large ships	...	...	...	...	75,000 yds.
WS sets in A/S escorts	...	...	...	...	15,000 yds. with an occasional sweep on 75,000 yds.
WC sets	...	...	...	...	75,000 yds.

(d) **The pulse length to use** if other than normal. Warning sets normally use long pulse length.

Note to (a)–(d). "Normal Sweep and settings" should be ordered by the Controlling position when so desired. The occasions on which it may be desirable to depart from normal sweep or settings are explained in *Part II*.

(e) **The radar policy for interrogators**, *i.e.*, whether interrogation may be carried out automatically or only by order from the controlling position.

(f) **Information on the situation** which will help the operator to show an intelligent appreciation of the situation and therefore in turn help the Controlling Officer. Information should include the position and movements of ships in company (or the bearing limits of the Convoy), whether any ships or land are likely to be met with, and details of the zig-zag if in force. Even if P.P.I. is fitted, the operator should be provided with a small mooring board on which the relative position of ships in company can be plotted. Ships in company and other known objects in steady proximity (such as A/S patrol aircraft showing I.F.F.), when once identified by radar, are not reported unless ordered or unless the operator considers that fresh and important circumstances make a report necessary.

* The Controlling Positions are :—

For aircraft warning ... A.D.R.

For surface warning ... Operations Room (O.R.) or alternatively the bridge in small ships.

FIRST REPORT OF AN ECHO

6. The essence of a first report is speed rather than accuracy, and details are confined to bearing and distance, *e.g.*,

"Echo bearing two seven oh, distance twenty (or forty thousand)."

Notes:—

(a) the distance is reported in miles when the scale is graduated in miles (*e.g.*, WA sets), and is reported as a range in yards when the scale is graduated in yards (*e.g.*, in WS and WC sets). (In gunnery radar sets, the range is reported in hundreds of yards as a three figure group, *e.g.*, *"Oh five three."*)

(b) the classification of echo may also be given in a first report if it is at once obvious, *e.g.*, an aircraft.

7. Unless the radar policy restricts the use of interrogators, the operator will then, in the case of a new echo, train the interrogator and transmit for 10 seconds, reporting either *"Showing I.F.F. Code—"* or *"Not showing I.F.F."*

AMPLIFYING REPORTS

8. The first report must be repeated back by the control position, and will be followed as soon as practicable by an **amplifying report**, the characteristics of which are:—

(a) Greater accuracy of bearing and range.

(b) Inclusion of subsidiary information such as classification of the echo, numbers of aircraft, and approximate height (see however *para. 25*).

9. The words "bearing," "distance" and "range" are omitted in an amplifying report, of which the following is an example:—

"Echo two seven three—nineteen—group of aircraft—height, one thousand."

ORDERS BY THE CONTROLLING POSITION AFTER RECEIPT OF A FIRST REPORT

10. After repeating back the first report, the controlling position will normally wait for the first amplifying report, which is made as soon as possible.

11. If no specific orders are given, the operator will continue to make amplifying reports at intervals of about two minutes. The exact interval will, however, depend on the number of other echoes under report, and also on the distance (near or far) at which the echo was first detected and its speed of approach.

12. Alternatively, the controlling position may order the operator to **"watch"** or **"hold,"** if more detailed or more continuous information is required, or to **"disregard."**

"Watch"

13. **"Watch"** is an order to pay particular attention to an echo and report it in detail on each occasion of sweeping past when using hand training and "A" display. When using P.P.I. display, the echo is reported about once a minute, or more frequently if ordered.

14. The order to "watch" does not however in any way alter the type or rate of sweep in force.

15. While an echo is being "watched" or "held" it is referred to as a **"Target."** If several echoes are being watched they are called **"Target A," "Target B,"** and so on, these letters being allocated by the controlling position.

16. It is not practicable for more than about 6 reports to be made per minute. The controlling position must therefore exercise discrimination between which echoes are to be watched and which are to be reported normally. Too many "targets" will leave no time to observe and report other echoes.

17. When particular interest in a target no longer remains, the operator should be ordered to **"cease watching"** (if normal reports only are required), or to **"disregard"** (see *para. 21*).

"Hold"

18. **"Hold"** is an order to concentrate attention on a particular target and pass reports as frequently as practicable.

19. The order to hold means that the sweep is interrupted and the aerial kept trained on the target until further orders, and consequently all round warning and P.P.I. display is lost. A target should therefore only be held under very exceptional circumstances, *e.g.*, a U-boat at close range, when following a target to extreme range, or when using the WS set for gunnery ranging.

20. When a target need no longer be held the order **"Resume Sweep"** should be given. The last ordered type and rate of sweep is then carried out.

"Disregard"

21. If an echo is of no further interest the operator should be ordered to **"Disregard"** in which case he will cease reporting it and told the reason (*e.g.*, "Eddystone Lighthouse"). The operator should however resume reporting if, owing to an important change in the behaviour of the echo, he considers it should be reported again (*e.g.*, "Eddystone Lighthouse" starts closing at 300 knots).

OTHER ORDERS AND REPORTS WHICH MAY BE GIVEN OR RECEIVED

"Investigate"

22. "Investigate" is an order to carry out a special search over a particular sector, e.g., if the approach of E-boats from a particular direction is suspected. Example:—

"Investigate oh two oh to oh four oh."

23. Naturally, all round warning is lost and with spinning sets (e.g., type 277) hand training must be adopted.* Full P.P.I. display is lost, but the P.P.I. may still be of some value. The speed of sweep should be as fast as possible if P.P.I. is used, but slower than normal if "A" display is used.

24. The operator will continue to investigate between the bearings ordered until ordered to resume sweep, reporting "Arc Investigated" after the first investigation and subsequently at intervals.

"Interrogate"

25. Normally the operator will interrogate a new echo automatically on first detection, *vide para. 7*. If however the use of interrogators is restricted for security reasons, the Controlling Officer must order "interrogate" when required, in the light of the tactical situation and weighing the advantage and disadvantage of transmitting on the interrogator (Chapter XIX).

"Height"

26. As soon as aircraft are first detected, the operator will when possible report an approximate height. If a series of more accurate heights of a particular target are required, e.g., for fighter direction, the operator or Height Filtering Position (if fitted) must be told to pass in "Heights of Target—", and will then endeavour to do so at intervals of 2–3 minutes.

27. It must be appreciated that unless a sector display panel is fitted, the requirement for accurate height involves holding the target for considerable periods if using WA type 79/B, and thus reducing the efficiency of all-round warning. Heights of more than two targets should not therefore normally be asked for at the same time. With WA type 281/B fairly accurate heightfinding can be carried out without stopping the sweep provided the sweep rate does not exceed 2 r.p.m.

28. The operator should be instructed "Target...Cease heightfinding" when heights are no longer required.

"Target Lost"

29. The operator will report "Target Lost" with the bearing and range when detection is no longer possible. When dealing with a small fluctuating echo such as a U-boat at extreme range, the operator may report "Target regained" if it is clearly the same target, otherwise he will make a fresh "First report."

CEASING OPERATING AND CLOSING DOWN

30. The control officer will order "Cease operating" when radar is not immediately required, but the office is to remain manned with the set kept warmed up and ready to operate. The order "Close down" should be given when radar is no longer required and the operator can fall out.

ECHOES TO BE REPORTED

31. The operator must report all echoes detected except:—

- (a) Ships in company, and other targets referred to in *para. 5 (f)*, once these have been identified.
- (b) Echoes which he has been told to "Disregard" (but see *para. 21*).

If there are so many echoes that the operator is unable to report them all at reasonable intervals, he should report the fact and should be given instructions on which echoes to concentrate.

MISCELLANEOUS POINTS

Acknowledging and repeating back orders

32. The following should always be repeated back:—

- (a) First reports.
- (b) Control orders.

Other information should be acknowledged only.

33. The radar office may be addressed either by type number or by classification, e.g.,

"A.D.R.—WA."

"O.R. —WS." or "Bridge—271."

* Note. Some sets (e.g. WS types 268 and SL) have no hand control, and it is therefore not possible to "Investigate."

Classification of echoes—assistance to operators

34. If operators are to acquire skill in classifying echoes, it is essential that controlling positions should inform them of the exact nature of the target when this eventually becomes known. This is particularly important as regards numbers of aircraft in a group.

35. The height of aircraft when sighted should also be communicated, for comparison with the last radar height estimation.

Switching off I.F.F. during interrogation

36. If own ship's I.F.F. interferes with efficient operation of the Interrogator, as sometimes happens, the operator has authority to switch off I.F.F. whilst actually interrogating.

Operators' log

37. A record of all orders received and reports made is entered in the Operators' Log which is kept by the operator not actually reading the trace at the time. Details are contained in Radar Operating Procedure. Drill for Warning Sets. Efficient operation of the set and efficient reporting must, however, take precedence over entering details in the log.

38. The log must be signed by the operator at the end of each trick, and should be inspected periodically.

Turning over a watch

39. At the end of a watch the operator is responsible for turning over to his relief the general instructions and information he has received (*para. 5*) and any detailed orders (watch, disregard, etc.) about echoes under detection.

Radar office clocks, gyro compass repeaters and remote displays

40. Radar office clocks and gyro compass repeaters should be checked with the controlling positions at the beginning of each watch. The aerial alignment of Remote displays should similarly be checked.

CHAPTER XXIV

REPORTS ON RADAR

Reports on radar divide themselves into two kinds :—

- (a) **Operational**, *i.e.*, reports dealing with the use of equipment in action and in exercises.
- (b) **Technical**, *i.e.*, reports dealing with defects and maintenance problems, and suggesting improvements.

2. Although the forwarding of reports is often irksome, their timely receipt is of great importance and it can be stated that even if they are not always answered they are always read, and action taken where possible. The general dissemination of information such as is contained in this book, "*Fighting Experience*," and the various Radar Bulletins must be based on reports from sea ; while action experience must form the basis when formulating new radar staff requirements and deciding upon which radar projects our finite development staff should concentrate.

3. On the purely technical side, the rectification of faults and provision of extra spares again depends upon information reaching Admiralty and A.S.E., while ships are often able to suggest minor improvements which can be incorporated in standard equipment.

4. It is clear, therefore, that ships have a considerable responsibility for forwarding reports on radar.

OPERATIONAL REPORTS

5. Operational reports include

- (a) Reports on actions and exercises.
- (b) Reports on firings.
- (c) Special reports.

Action Reports

6. The use made of radar should be included in reports of action, and also reports of large scale or special exercises. It will often be convenient to group the information together in an Appendix. The following points should always be covered if applicable :—

- (a) Radar policy in force prior to the engagement.
- (b) Details of initial detections, with type of sweep in force, and subsequent radar ranges and bearings as relevant to the narrative.
- (c) The use made of other ships' radar information, and remarks on the radar inter-reporting system.
- (d) The functioning of gunnery radar equipment.
- (e) The functioning of the radar recognition system (Interrogators and I.F.F.).

Firings

7. Details of the information required in gunnery radar reports on firings, whether in action or practice, are given in *C.B. 4212(I) Chapter XI*. A.A. actions are covered by *Form S1515*.

Special reports

8. Special reports may be forwarded at any time, and may include suggestions on new applications of radar or proposals concerning radar operating procedure (drill).

TECHNICAL REPORTS

Defects

9. Radar technical defects should be reported on *Form S1183* direct to A.S.E., where they are analysed and the appropriate measures taken where possible. Reference to technical defects may also be made in reports of proceedings, etc.

10. Gunnery radar defects should be reported on *Form S1148(h)* (Failure of Gunnery material) in addition to *Form S1183*.

Routine Reports

11. In accordance with C.A.F.O's ships are required to render Routine Reports to Admiralty, for Director of Radio Equipment (copies to the Administrative Authority and A.S.E.), as follows :—

(a) Report No. 1 (Equipment fitted)

A list of the radar equipment fitted, to be forwarded within one month of refit.

(b) Report No. 2 (Alterations and suggestions)

(i) Alterations, other than those authorised by A.F.O., giving the authority or reason.

(ii) Authorised modifications not yet carried out.

(iii) Suggestions for improvement.

To be forwarded half yearly, on 1st February and 1st August.

(c) Report No. 3 (Performance)

A summary, based on experience at sea and the records kept in the operators' log, of the actual performance against targets of various size and/or height for all radar sets fitted. The accurate compilation of this report is of the first importance as it is the main guide to whether radar sets in service are giving the performance for which they are designed. This report is therefore the criterion of good design and good maintenance. Reports number 3 should be forwarded after 6 months' experience of the set or sets.

Special reports

12. Special reports should be forwarded at any time to cover any unusual point or suggestion of technical experience or interest. Whether or not the suggestion is ultimately incorporated as part of standard equipment, it is often desirable to promulgate it generally as advance information, e.g., in the "*A.S.E. Bulletin*."

13. Alternatively, it is sometimes possible to prevent a ship perpetuating an apparently advantageous modification which, in the light of knowledge not available to the ship concerned, has been found to introduce the probability of undesirable consequences. As an example, the useful suggestion of using panel L18 with type 284 came from sea, but the method of inter-switching as originally suggested introduced a ranging error.

COPIES OF REPORTS, AND AUTHORITIES INTERESTED

14. It is perhaps not generally realised at sea that owing to the large number of interested Divisions, Departments and Authorities inside and outside Admiralty, circulation of reports and therefore necessary action is likely to be delayed if too many subjects are dealt with at the same time; indeed a good maxim is "One Subject, one report." Where this is not possible, it is advantageous to provide additional copies so that advance action may be taken on each separate subject.

15. Alternatively, and subject to the instructions of the Administrative Authorities, copies may usefully be given to specific authorities. The following list of the principal interested authorities may therefore prove useful:—

AUTHORITY, ETC.	SUBJECT.
(i) Admiralty, Director of Radio Equipment Department (D.R.E.).	Use of all radar equipment. All radar technical questions. Radar maintenance questions (including personnel).
(ii) Captain Superintendent, Admiralty Signal Establishment.	Ditto
(iii) Admiralty, Director of Tactical, Torpedo and Staff Duties Division (D.T.S.D.).	Use of radar for tactical purposes and torpedo control. Personnel matters (other than maintenance).
(iv) Admiralty, Director of Gunnery and A.A. Warfare Division (D.G.D.).	Use of radar for gunnery fire control. The R.C. Branch.
(v) Admiralty, Director of Naval Ordnance	Gunnery/radar equipment.
(vi) Admiralty, Director of Air Warfare and Flying Training Division (D.A.W.T.)	Use of radar for Fighter Direction.
(vii) Admiralty, Director of Navigation (D. of N.).	Use of radar for Navigation. The R.P. Branch.
(viii) Admiralty, Director of A/S Warfare Division (DA/SW).	Use of radar in A/S warfare.
(ix) Captain Radar Training, H.M.S. Collingwood	Personnel and Training.

APPENDIX I

PERFORMANCE TO BE EXPECTED FROM RADAR SETS IN SERVICE

1. Below are listed the results which should be obtained from R.N. and certain U.S. Radar sets under service conditions.

2. As a rule, if sets do not produce the results shown they are not working at proper efficiency and they should be specially examined to find the reason.

3. It is however possible that with sets having a slow rate of sweep (such as types 272 and 291) optimum results will not be achieved, particularly against fast closing targets. Similarly, detection of aircraft by sets whose vertical coverage diagrams have numerous gaps (such as types 291, S.A. and S.K.) may be unreliable especially at their longest ranges.

4. *Surface and low flying aircraft warning.*—(a) For a given set results depend upon the height of aerial. Typical cases only are shown. For other heights results will differ approximately as the square root of the ratio of heights concerned.

(b) Where optical horizon range is mentioned it refers to the distance between own ship's aerial and the top of the target's superstructure (not her mast).

(c) *Reliable and maximum ranges.*—Reliable range is that at which the echo height is sufficient for the target not to be missed by an average operator and assumes a normal sweep rate. Maximum range is that to which the target should be subsequently followed.

(d) High power centimetric sets (such as types 276, 277, 293 and sometimes type 271/3 Q) will, under conditions of anomalous propagation, give results greatly in excess of the normal figures shown, but these exceptional results must not be depended upon. Anomalous conditions are most frequent in hot climates on windless days.

5. *Aircraft Warning.*—The results shown are those to be expected against one medium bomber or two fighters, and assume that the longest pulse-length is in use. Using a short pulse length, with the object of getting better discrimination will reduce warning by up to 20 per cent. On the other hand, in the case of WS and WC sets, a large bomber will give results 25 per cent. greater.

WA (WARNING AIRCRAFT) SETS

Types 79, 79B, 279	Battleship or Fleet Carrier with Aerial at 150 ft. miles	Cruiser or Escort Carrier with Aerial at 100 ft. miles
Against Aircraft at 20,000 ft.	97	87
15,000	85	75
10,000	70	62
5,000	50	44
1,000	25	19

Type 281/B	Battleship with Aerial at 150 ft. miles	Cruiser or Fleet Carrier with Aerial at 110 ft. miles
Against Aircraft at 20,000 ft.	117	110
15,000	105	98
10,000	87	80
5,000	62	58
1,000	29	27

Note: Pre-amplifier when fitted is expected to increase ranges 10–15%, reduce gaps, and improve high cover.

U.S. Type SA	Frigate, Aerial at 70 ft. miles
Against Aircraft 5,000 ft. and above	35–50
1,000 ft.	25
See Note (3).	

U.S. Type SK	Escort Carrier, Aerial at 100 ft. miles
Against Aircraft at 20,000 ft.	120 (unreliable)
15,000	110
10,000	90
5,000	65
1,000	30
See Note (3).	

WS (WARNING SURFACE) SETS

Type 268

M.T.B./M.G.B. (aerial 20 ft.)	Against	Large ship ...	Reliable yards 30,000
		E-Boat ...	7-8,000

Very low aircraft may be detected at 2-3 miles.

Note: Type 268 results are forecast figures only.

Type 271Q

			Reliable yards	Maximum yards
Destroyer, frigate, corvette (aerial at 30-45 ft.)	Against	Battleship ...	26,000	29,000
		Large cruiser ...	24,000	27,000
		Small cruiser ...	21,000	24,000
		Destroyer ...	18,000	21,000
		E-Boat ...	9,000	12,000
		U-Boat ...	8,000	11,000

Low flying aircraft can be detected at 20-25,000 yards.

Type 272P

(a) Cruiser (aerial at 80 ft.)	Against	Battleship ...	30,000	33,000
		Large cruiser ...	26,500	30,000
		Small cruiser ...	24,000	27,000
		Destroyer ...	17,500	19,000
		E-Boat ...	8,500	9,500
		U-Boat ...	7,500	8,000
(b) Destroyer (aerial at 70 ft.)	Against	Battleship ...	24,000	26,000
		Large cruiser ...	22,000	24,000
		Small cruiser ...	20,000	22,000
		Destroyer ...	16,000	17,500
		E-Boat ...	7,000	8,000
		U-Boat ...	6,000	7,000
(c) Sloop (aerial at 35 ft.)	Against	Battleship ...	19,000	21,000
		Large cruiser ...	16,000	18,000
		Small cruiser ...	14,000	16,000
		Destroyer ...	11,000	13,000
		E-Boat ...	6,000	7,000
		U-Boat ...	5,000	6,000

See note (3).

Type 273Q

(a) Battleship (aerial at 100 ft.)	Against	Battleship ...	46,000	50,000
		Large cruiser ...	43,000	47,000
		Small cruiser ...	39,000	42,000
		Destroyer ...	36,000	39,000
		E-Boat ...	17,000	20,000
		U-Boat ...	15,500	17,000
		Low flying aircraft can be detected at 30-40,000 yards.		
(b) Cruiser (aerial at 65 ft.)	Against	Battleship ...	35,000	40,000
		Large cruiser ...	33,000	37,000
		Small cruiser ...	30,000	34,000
		Destroyer ...	26,000	29,000
		E-Boat ...	14,000	17,000
		U-Boat ...	12,000	15,000

Low flying aircraft can be detected at 25-30,000 yards.

Type 276

Surface targets.

			Reliable yards
(a) Battleship (aerial AUJ at 150 ft.)	Against	Battleship ...	50,000
		Large cruiser ...	47,000
		Small cruiser ...	44,000
		Destroyer ...	39,000
		E-Boat ...	20,000
		U-Boat ...	19,000
(b) Destroyer (aerial AUJ at 70 ft.)	Against	Battleship ...	38,000
		Large cruiser ...	35,000
		Small cruiser ...	31,000
		Destroyer ...	27,000
		E-Boat ...	14,000
		U-Boat ...	12,500

Aircraft targets

			Reliable yards	Maximum yards
With aerial AUJ				
Against aircraft between 200 ft. and 6,000 ft.	...	...	25,000	35,000

Type 277*Surface targets.*

Reliable results on targets larger than a destroyer should be equal to optical horizon range, *i.e.* :—

		<i>yards</i>	
(a) Battleship (aerial at 100 ft.)	<i>Against</i>	Battleship ...	47,000
		Large cruiser ...	44,000
		Small cruiser ...	40,000
		Destroyer ...	37,000
		E-Boat ...	23,000
		U-Boat ...	22,000
(b) Frigate (aerial at 32-40 ft.)	<i>Against</i>	Battleship ...	36,000
		Large cruiser ...	32,000
		Small cruiser ...	29,000
		Destroyer ...	23,000
		E-Boat ...	14,000
		U-Boat ...	13,000

Aircraft targets.

Fleet Carriers (aerial at 80 ft.)

(a) With aerial laid on horizon, aircraft up to about 5,000 ft. should be detected as follows :—

Aircraft at 4,000-5,000 ft. ...	25 miles
3,000 ...	28 miles
1,000 ...	40 miles

(b) With aerial elevated above $3\frac{1}{2}^\circ$ aircraft should be detected and height-finding possible to 25 miles.

(c) Above $3\frac{1}{2}^\circ$ elevation accuracy should be $\frac{1}{2}-\frac{3}{4}^\circ$ (*i.e.* 1,200-2,000 ft. at 25 miles).

Type 970

L.C.H. or M.L. (aerial at 30 ft.)

		<i>Reliable yards.</i>	<i>Maximum yards.</i>
<i>Against</i>	Merchant vessel (5,000 tons)	16,000	20,000
	Destroyer ...	14,000	16,000
	M.L. or L.C.T. ...	6,000	7,500
	L.C.P. ...	3,000	4,000
	Cliffs over 500 ft. ...	40,000	50,000
	Cliffs at 100 ft. ...	30,000	35,000
	Cliffs at 20 ft. ...	8,000	9,000
	Land, 100 ft., slightly sloping	21,000	25,000
	Land, 10 ft. slightly sloping	5,000	7,000

(When modified aerial is fitted, add 15 per cent. to results given above.)

U.S. Type SG

.S. Type SG				Reliable range	
				SG yards	SG1/SG1a yards
Escort carrier (aerial at 96 ft.)	Against	Large ship ...	37,000	43,000	
		Medium ship ...	31,000	35,000	
		Small ship ...	24,000	30,000	
		U-Boat ...	12,000	15,000	
		Low flying aircraft can be detected up to about 30,000 yards.			
Frigate (aerial at 75 ft.)		Large ship ...	33,000	38,000	
		Medium ship ...	28,000	31,000	
		Small ship ...	21,000	27,000	
		U-Boat ...	9,000	12,000	
		Low flying aircraft can be detected up to about 25,000 yards.			

U.S. Type SL

.S. Type SL			Reliable range yards
Frigate (aerial at 75 ft.)	Against	Large ship ...	37,000
		Medium ship ...	33,000
		Small ship ...	24,000
		U-Boat ...	11,000
Low flying aircraft can be detected up to about 30,000 yards.			

WC (WARNING COMBINED) AND TARGET INDICATION SETS

Type 267W

(centimetric portion of set)

S/M (aerial at 20 ft.)

Against

Large ship ...
 Medium ship ...
 E-Boat ... }
 U-Boat ... }

Reliable
yards

30,000
 20,000
 10,000

Very low aircraft may be detected at 3-4 miles.

Note : The above results are forecast figures only. For the metric portion of the set see under type 291W.

Type 291/U/W

Surface targets.

(a) Type 291 in Destroyer (aerial at 80 ft.)

Against

Battleship ...
 Large cruiser ...
 Small cruiser ...
 Destroyer ...
 E-Boat ... }
 U-Boat ... }

Reliable
yardsMaximum
yards

17,000 20,000
 14,500 18,000
 13,000 15,000
 11,500 13,500
 6,000 7,000

(b) Type 291U in M.T.B. (aerial at 20 ft.)

Battleship ...
 Large cruiser ...
 Small cruiser ...
 Destroyer ...
 E-Boat ... }
 U-Boat ... }

9,000 11,000
 7,500 9,000
 6,500 7,500
 6,000 7,000
 3,500 4,000

(c) Type 291W in S/M (aerial at 30 ft./40 ft.)

Against

Battleship ...
 Large cruiser ...
 Small cruiser ...
 Destroyer ...
 E-Boat ... }
 U-Boat ... }

11,000/4,000 13,000/5,000
 9,000/3,500 10,500/4,500
 8,000/3,000 9,000/4,000
 7,000/3,000 8,000/3,500
 5,000/1,500 5,500/2,000

See note (3).
 Aircraft targets.

	Feet	Destroyer with aerial ATQ or ATR at 80 ft. miles	Destroyer with aerial ATQ or ATR at 35 ft. miles	MTB with aerial ATS at 20 ft. miles	S/M with aerial ATT miles
Against aircraft at	20,000	30-35	35	nil	30-35
	15,000	30-35	25	nil	30-35
	10,000	30-35	17	15	30-35
	5,000	30-35	32	22	30
	1,000	23	15	12	15

See note (3).

Type 293/M

Surface targets.

(a) Battleship (aerial AUR at 150 ft.)

Against

Battleship ...
 Large cruiser ...
 Small cruiser ...
 Destroyer ...
 E-Boat ...
 U-Boat ...

Reliable
yards

42,000
 39,000
 35,000
 30,000
 15,000
 14,000

(b) Destroyer (aerial AUR at 70 ft.)

Against

Battleship ...
 Large cruiser ...
 Small cruiser ...
 Destroyer ...
 E-Boat ...
 U-Boat ...

30,500
 28,500
 25,500
 24,000
 11,500
 10,000

Aircraft targets

With aerial AUR against aircraft between 100 ft. and 20,000 ft. ...
 With aerial AQR (type 293M) against aircraft between 100 ft. and 20,000 ft. ...

Reliable
yardsMaximum
yards

15,000 20,000
 18,000 25,000

Note : Type 293 results are forecast figures only, and will be confirmed after more sea experience.

HEIGHTFINDING SETS**U.S. Type SM1**

(a) *Heightfinding accuracy* up to 50 miles is 10-15 minutes (*i.e.* 500 ft. at 25 miles, 1,000 ft. at 50 miles).

(b) *Aircraft targets* of sufficient height can be followed further, up to 75 miles but without height-finding.

(c) *Surface targets* larger than a destroyer can be detected to horizon range if the aerial is laid on the horizon.

GUNNERY SETS

Surface targets.—(Note : performance varies with the height and type of aerial fitted.)

GS Type 274.

				<i>Reliable yards</i>	<i>Maximum yards</i>
(a) Battleship (aerial AUM at 100 ft.)	<i>Against</i>	Battleship	...	42,000	—
		Large cruiser	...	41,000	—
		Small cruiser	...	40,000	—
		Destroyer	...	38,000	—
(b) Cruiser (aerial AUO at 60 ft.)	<i>Against</i>	Battleship	...	—	—
		Large cruiser	...	—	—
		Small cruiser	...	—	—
		Destroyer	...	—	—

GA Type 275

(a) Cruiser (aerial at 60 ft.)	<i>Against</i>	Battleship	...	—	—
		Large cruiser	...	—	—
		Small cruiser	...	—	—
		Destroyer	...	—	—
(b) Destroyer (aerial at 40 ft.)	<i>Against</i>	Battleship	...	—	—
		Large cruiser	...	—	—
		Small cruiser	...	—	—
		Destroyer	...	20,000	—

Note : Type 275 results are forecast figures only, and will be amplified after sea experience.

GC Types 282 M/P and 283

Surface vessels larger than trawlers should be detected up to the limit of the scale (6,000 yards).

GS Type 284 M/P

(a) Battleship (aerial ASF at 100 ft.)	<i>Against</i>	Battleship	...	30,000	32,000
		Large cruiser	...	26,500	28,000
		Small cruiser	...	24,000	25,500
		Destroyer	...	18,000	19,000
(b) Cruiser (aerial ASF at 60 ft.)	<i>Against</i>	Battleship	...	26,500	28,500
		Large cruiser	...	20,000	21,500
		Small cruiser	...	18,000	19,000
		Destroyer	...	16,000	17,000

GA Type 285 M/P

(a) Cruiser (aerial ASG at 60 ft.)	<i>Against</i>	Battleship	...	22,000	24,000
		Large cruiser	...	18,000	19,500
		Small cruiser	...	16,000	17,000
		Destroyer	...	13,000	14,000
(b) Destroyer (aerial ASG at 40 ft.)	<i>Against</i>	Battleship	...	17,500	19,500
		Large cruiser	...	16,000	17,500
		Small cruiser	...	14,000	15,000
		Destroyer	...	10,000	11,000

Aircraft targets.

GC Type 262**GA Type 275**

Forecast results, which are subject to sea experience, are 30,000 yards maximum and 20,000 yards reliable against a medium bomber.

GC Types 282 M/P and 283

Aircraft should be detected up to the limit of the scale (6,000 yards).

GS Type 284 M/P

The set is not designed for aircraft detection, but low flying aircraft can be detected, *e.g.* up to 40,000 yards from a battleship against aircraft at 1,000 ft.

GA Type 285 M/P

Performance does not materially alter with height of aerial, but depends to some extent on elevation of the director. Optimum results are :—

					<i>From Battleship yards</i>	<i>From Destroyer yards</i>
Against aircraft at 20,000 ft.	...	...	...	...	23,000	24,000
10,000 ft.	...	...	...	...	36,000	26,000
5,000 ft.	...	...	...	...	38,000	28,000
1,000 ft.	...	...	...	...	40,000	30,000

BEARING ACCURACY FOR BLIND FIRE*Accuracy***GC Type 262 against aircraft targets****GC Types 282/M/P and 283 against aircraft targets**

Type 282 } if fitted with remote bearing tube or R.P.C.	...	...	30 minutes.
Type 283 }			
Type 282 without bearing tube.	...	...	2 degrees.

Note.—In practice the attainment of the above bearing accuracies is very dependent on operating conditions, experience of operators, and accurate transmission when the bearing tube is remote from the director.

GS Type 274 against surface targets ... 5 minutes.**GA Type 275 against surface or aircraft targets.**

Bearing accuracy	...	...	...	...	15 minutes.
Elevation accuracy against aircraft targets, except when between $\frac{1}{2}^{\circ}$ and $3\frac{1}{2}^{\circ}$	...	...	...	...	15 minutes.

Note.—The above results for type 275 are forecast figures only.

GS Type 284 M/P against surface targets.

Small rate of change of bearing	...	...	...	...	5 minutes.
Large rate of change of bearing	...	...	...	...	10 minutes.

GA Type 285 M/P against surface or aircraft targets.

Small rate of change of bearing	...	...	...	...	15 minutes.
Large rate of change of bearing	...	...	...	...	30 minutes or more.

SPLASH SPOTTING RANGES

In calm weather, and provided salvo is in line.

GS Type 274*Reliable range
yards*

14-in. K shell set non-delay (single shot)	...	...	...	...	35,000
14-in. A.P.C.	...	...	...	...	25,000 plus
6-in. (6-gun salvo)	...	...	...	...	23,000

GA Type 275.

4-in. shell	...	...	...	...	11,500*
4.5-in. shell	...	...	...	...	14,500*

* Forecast figures.

GS Type 284 M/P.

14-in., 15-in. and 16-in. A.P.C. "K" (3-gun salvo)	...	...	...	20,000
6-in. and 8-in. G.P.B.C. "K" (6-gun salvo)	...	...	...	15,000
4-in., 4.5-in. and 4.7-in. (4-gun salvo)	...	...	...	8,000

~~CONFIDENTIAL~~

Attention is called to the penalties attaching to any infraction of the Official Secrets Acts.

C.B. 4182/45 (I)

Addendum No. I

TO

RADAR MANUAL

(Use of Radar)

1945

ADMIRALTY, S.W.1,
RADIO EQUIPMENT DEPARTMENT.
(R.E. 02304/45)

Amendment No.	C.A.F.O. P. No.	Date of insertion in this copy.	Initials.
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SEARCHING FOR A U-BOAT AT SCHNORKEL DEPTH

Procedure in Escort Vessels using P.P.I.

1. The following notes on carrying out a sweep to detect U-Boats at schnorkel depth are based on experience gained in Western Approaches Command during the latter part of the war against German U-Boats and in sea trials against a submarine fitted with a mock-up schnorkel. Such information can, therefore, only be taken as a guide for any future radar procedure which may be devised for improved types of radar equipment in advance of Radar, Type 277. It has been assumed that the schnorkel was not fitted with a pressure-tight 10 cm. search receiver or covered with anti-radar materials. It will be noticed that the procedure is essentially a system by which radar information is checked by asdics and vice-versa.

2. A schnorkel is not a good radar target. Experience has shown, however, that with wave heights below 3 ft. there is a reasonably good chance of detecting a schnorkel at ranges of 2,000 to 3,000 yards. It is essential that operators are carefully instructed in the procedure to be adopted and have taken part in exercises against a submarine fitted with a schnorkel. With wave heights greater than 3 ft. detection of schnorkel is very unlikely with existing types of radar sets. In trials slightly greater ranges have been obtained along the troughs of the sea than across the sea.

3. Although trials have shown that in seas of force 22 and below a schnorkel can be detected at ranges of 2,500 to 5,000 yards, in practice, considerable difficulty is experienced by echoes from sea-gulls and floating objects when the sea is smooth, and from wave echoes when the sea is slight. It is important, therefore, that a means should be available for rapidly confirming whether radar echoes, detected between 1,500 and 5,000 yards, are genuine schnorkel echoes or are caused by other targets. At night, or in low visibility, the only means readily available for confirming whether a small echo is a schnorkel or not is to attempt to obtain an asdic echo, closing to asdic range as requisite. If danger from acoustic homing torpedoes exists, the search should be carried out at safe speed.

Searching Procedure

4. In view of the above considerations a sweep designed to detect U-Boats at schnorkel depth should be carried out as follows:—

- (a) Ships should be in line abreast about 4,000 yards apart. This distance reduces the chance of side echoes appearing on the displays at a range of 2,000 to 3,000 yards, at which schnorkel detection by radar is most probable. This distance also allows ships room to manoeuvre independently while investigating contacts, while at the same time, ensuring that the search is reasonably thorough.
- (b) Radar operators should be instructed that schnorkelling U-Boats may be expected, and that they must, therefore, concentrate on the area up to 4,000 to 5,000 yards from the ship. It is essential that all echoes which paint twice on the P.P.I. are reported.
- (c) The operator in the office must pay particular attention to the first 4,000 to 5,000 yards of the display, a considerable reduction in the amount of "reporting" which can be carried out from the office P.P.I. will have to be accepted. This difficulty has been overcome by employing two ratings in the plot, one plotting and the other reporting from the remote P.P.I. In which case more use will have to be made of the remote P.P.I. for navigation and manoeuvring purposes.
- (d) As escorts will be leaving station at frequent intervals to investigate radar echoes, radar operators should be instructed to report whenever a consort closes to within 2,000 yards.
- (e) As each "possible schnorkel" radar echo is reported, it should be confirmed by asdic, using hand transmission if outside 2,500 yards and closing as necessary. Even with radar reports limited as in sub-paragraph (b) above, it is probable that a large number of radar echoes will have to be investigated in a short time.
- (f) As a U-Boat at schnorkel depth does not normally provide a very good asdic target all "possible schnorkel" targets first detected by asdic should be checked by radar.

5. In good visibility by day, experienced look-outs will detect a schnorkel at greater range than radar.

6. The optimum speed of aerial rotation for Radar, Type 277, has been found to be 6 to 8 r.p.m.

7. The office P.P.I. should be set up for maximum sensitivity.